# Detection of PIT-Tagged Juvenile Salmonids in the Columbia River Estuary using Pair-Trawls, 2008

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## EXECUTIVE SUMMARY


In 2008, we continued a study using a surface pair-trawl fitted with a detection system to detect juvenile Pacific salmonids *Oncorhynchus* spp. implanted with passive integrated transponder (PIT) tags. We operated the trawl in the upper Columbia River estuary between river kilometer (rkm) 61 and 83, sampling for a total of 976 h between 7 March and 20 August and for an additional 60 h between 29 September and 30 October. We detected 16,563 PIT-tagged juvenile anadromous salmonids of various species, runs, and rear types. Among the annual total detections, 16% were wild fish and 81% were hatchery-reared, with the remaining 3% composed of fish from unknown origins. Of all fish detected, 61% were Chinook salmon, 36% were steelhead, and 3% were other salmonid species or unknown species.

We began sampling in spring 2008 using the same cylindrical antenna system used in 2007. The cod end of a Nordic surface trawl was replaced with an antenna system for detecting PIT-tagged fish. In 2008, we also finalized the development of a prototype “matrix” antenna, which had a fish passage opening about 12 times larger ($2.6 \times 3.0$ m) than that of the 0.9-m diameter cylindrical system.

We tested detection efficiency of the matrix antenna system by deploying it simultaneously with the cylindrical system. We deployed both systems within 1 km of each other during three daylight periods of relatively high fish densities (13, 14, and 15 May). During nearly 14 h of simultaneous sampling, unique fish detections on the matrix system surpassed those of the cylindrical system by 53%. We believe that the higher detection of the matrix system was due to fewer fish swimming forward, out of the trawl entrance, and to more fish passing readily through the larger passage opening. Deployment/retrieval of the matrix system was also more efficient and required fewer personnel; thus, following the tandem testing days, we sampled exclusively with the matrix system.

During the spring migration period, we targeted yearling migrants, including 825,740 yearling Chinook salmon and 342,071 steelhead PIT-tagged and released into the Snake River. Some of these fish were diverted for transportation at Lower Granite, Little Goose, Lower Monumental, or McNary Dam. Transported fish were generally released just downstream from Bonneville Dam, the lower most dam on the Columbia River, located about 150 km upstream from our sample site.

We began sampling on 7 March, coincidental with the arrival of early migrating juvenile PIT-tagged salmon and steelhead in the estuary. Sample effort began with a single crew operating 3-5 d/week and gradually increased to two shifts daily during

30 April-14 June as large numbers of yearling Chinook salmon and steelhead from Snake River releases arrived in the estuary.  Beginning on 18 May, high rivers flows and extreme debris loads frequently resulted in loss of sampling time, with seven shifts cancelled and several other shifts curtailed due to problems with gear and equipment, net damage, and significantly longer vessel transit times.

During the two-shift period, mean sample time was 12 h/d (1 h less than in 2007). We also detected 2.4% of the Chinook salmon and 3.6% of the steelhead previously detected at Bonneville Dam (compared to 3.9 and 3.6%, respectively, in 2007).  We detected 1.7% of the Chinook salmon and 1.9% of the steelhead that had been transported and released below Bonneville Dam (3.0 and 2.5%, respectively, in 2007).  In late June, sampling effort was decreased to a single daily shift (Monday-Friday), and on 20 August, sampling was halted altogether when detections of PIT-tagged fish declined (primarily subyearling fall Chinook salmon).

In 2008, 28% of fish detected in the trawl had been transported, and 13% had been detected in the bypass system or corner collector at Bonneville Dam.  The remaining 59% had no detection at a Snake or Columbia River dam (other than those with records of tagging at a dam), and a small portion of these were fish released below Bonneville Dam.  These detection history percentages were similar to those observed in previous years.

We maintained a near-constant daily sampling effort through the peak of the spring migration season.  Interruptions to sampling typically occurred due to high afternoon winds and vessel fueling and maintenance.  Mean detection rates during the two-shift sampling period were 14 fish/h during daylight and 27 fish/h during darkness for wild and hatchery yearling Chinook combined ($P = 0.034$).  For wild and hatchery steelhead combined, mean detection rates were 16 fish/h during daylight and 7 fish/h during darkness ($P = 0.122$).

Mean travel speed from Bonneville Dam to Jones Beach was significantly faster for yearling Chinook salmon detected at Bonneville Dam (93 km $d^{-1}$) than for those released from barges (70 km $d^{-1}$; $P = 0.000$).  There was also a significant difference in travel speed between steelhead detected at Bonneville (97 km $d^{-1}$) and those released from transport barges below Bonneville (94 km $d^{-1}$; $P = 0.000$).  Travel speeds for all fish groups were higher in 2008 than in 2007 because of river flows that were 27% higher in 2008 than in 2007.

Fall sampling in 2008 was conducted using the matrix antenna system and the shoreline matrix system.  Target fish during fall were subyearling Chinook salmon tagged and released in the Snake River. Recent evaluation of adult scale samples has revealed that a high proportion of Clearwater River Chinook released as subyearlings had in fact overwintered as juveniles in freshwater and entered the ocean as yearlings. Some of these fish had been transported and released below Bonneville Dam, and therefore were assumed to have overwintered in tidal freshwater or brackish water estuary areas.

We resumed sampling on 29 September, coincident with the expected timing of these fish in the upper estuary. We deployed the matrix trawl system 3 d/week and the shoreline system 2 d/week until 30 October. Only 3 fish (all Chinook salmon) were detected during the fall sample period: 1 Chinook salmon released from Little White Salmon Hatchery on 3 July (66 mm when tagged), 1 Chinook salmon released into the McKenzie River on 2 September (105 mm when tagged), and 1 Chinook salmon transported from Lower Granite Dam. This fish was detected on the shoreline system 5 d after tagging and 4.7 d after transport (163 mm when tagged).

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# INTRODUCTION

In 2008, we continued a multi-year study to detect juvenile anadromous Pacific salmonids *Oncorhynchus* spp. tagged with passive integrated transponder (PIT) tags using a surface pair trawl detection system (Ledgerwood et al. 2006, 2007; Magie et al. 2008). Seasonal sampling cruises with the trawl detection system began in 1995 and have continued annually (except 1997) in the Columbia River estuary near Jones Beach, approximately 75 river kilometers (rkm) upstream from the mouth of the Columbia River (Ledgerwood et al. 1997, 2003, 2006). Fish are guided into the trawl and exit through a passage opening fitted with an electronic detection antenna mounted in place of the cod-end (Ledgerwood et al. 2004). Target fish were those PIT-tagged in natal streams, hatcheries, or other upstream locations prior to or during migration (PSMFC 2008). As PIT-tagged fish exited through detection antennas in the trawl, their tag codes, time and date of detection, and GPS position were automatically recorded. Detections in the trawl system provide data for estimates of survival and evaluation of migration timing.

Nearly 2.4 million juvenile salmonids were PIT tagged and released into the Snake and Columbia River basins for migration in 2008 (PSMFC 2008). These fish were monitored during downstream migration using detectors installed by NOAA Fisheries and the U.S. Army Corps of Engineers (USACE) at hydroelectric facilities and in some streams throughout the basin (Prentice et al. 1990a,b,c). The Columbia Basin PIT Tag Information Systems (PTAGIS), a publicly available regional database, was used to store and disseminate release information, detection times and locations, as well as species, origin, and migration history of individual PIT-tagged fish detected in the trawl.

To divert fish from passing through turbine intakes, fish are guided through the spillways at dams using a removable spillway weir (RSW) or collected using submerged screens and routed to a juvenile bypass facility (JBS). Once in the JBS, fish can be routed back to the tailrace of the dam or transported past additional dams and released below Bonneville Dam, the lowermost dam on the Columbia River (rkm 234). In 2008, 363,794 PIT-tagged fish were transported. Detections in the estuary trawl system were used to monitor timing and survival of PIT-tagged fish. Tag data indicated whether fish detected in the estuary had migrated inriver through the hydropower system or had been transported past the dams for release below Bonneville Dam.

Detection data from pair-trawl sampling was collected with the following objectives:

1) Compare migration timing and estimate survival through the Columbia River hydropower system for inriver migrant and transported juvenile yearling Chinook

salmon *O. tshawytscha* and steelhead *O. mykiss* during the spring migration period.

2) Continue to provide multi-year analyses of survival through the Columbia River federal power system (CRFPS) of PIT-tagged salmonids during 1998-2008.

3) Continue to develop and test a larger detection antenna with its related equipment during the migration period. Use the larger system exclusively if indications warrant.

4) Extend sampling to the summer and fall period for subyearling Chinook salmon.

# METHODS

## Study Fish

We continued to focus sample effort on large release groups of PIT-tagged fish; in particular, inriver migrants detected passing Bonneville Dam and transported fish released just downstream from Bonneville Dam. The vast majority of these fish enter the upper estuary from late April through late July. During this period, nearly 940,000 PIT-tagged fish were released for a transportation study on the Snake River (D. Marsh, NMFS, personal communication) and nearly 217,000 PIT-tagged fish were released for a comparative survival study (PSMFC 2008). Of the PIT-tagged fish released in the Columbia River basin for migration in 2008, nearly 364,000 were diverted to transport barges and trucks and released downstream from Bonneville Dam. We also detected PIT-tagged fish from other major and minor studies, including a study of double-tagged fish (PIT and acoustic).

We coordinated our trawl system operations with the expected passage timing of these large groups based on their release locations and dates. After tagging at Lower Granite Dam, transportation study fish were either 1) released to the Snake River downstream from Lower Granite Dam (rkm 695) to continue their migration past the remaining dams, or 2) diverted to barges by collection and transport facilities at Little Goose Dam (rkm 635), Lower Monumental Dam (rkm 589), or McNary Dam (rkm 470).

Our transportation analysis included all PIT-tagged fish diverted to barges at all collector dams. We created a separate database for information associated with PIT-tagged fish recorded in PTAGIS as having been diverted, or possibly diverted, to transportation at any of the four transport dams. Intentional diversions of PIT-tagged fish at these dams were accomplished according to a “separation-by-code” (SbyC) procedure (Stein et al. 2004). Diversion to transportation barges either intentionally or unintentionally (i.e., missed being diverted back to the river at slide gates) was confirmed by comparing the last monitor name listed for a PIT-tagged fish to the PTAGIS site map to the route ending at a transport raceway or barge. Some fish were diverted to transportation, but their arrival in a transport-loading raceway could not be confirmed. These fish were flagged in our database, as were those removed for biological monitoring or other sampling purposes.

Since 1987, over 2.6-million PIT-tagged fish have been recorded in the PTAGIS database as having been transported. The USACE provided us with individual barge loading dates and times at each dam throughout the season. We then matched this barge loading information to the last detection date/time of diverted PIT-tagged fish on a transportation loading raceway. We assigned each fish with a detection on a transport loading raceway to the next available transport barge. Thus, we obtained specific barge release dates and locations of release for individual transported fish. Detections of these near-daily release groups of transported fish, when compared to fish detected passing Bonneville Dam on the same days, enabled a comparisons of relative travel speed and survival through the migration season.

In addition to the Snake River transportation study, several other studies in the Columbia River basin released large numbers of PIT-tagged juvenile salmonids. In this report, we focus our analyses on the more numerous PIT-tagged yearling Chinook salmon, subyearling fall Chinook salmon, and steelhead; however, detections of PIT-tagged coho salmon *O. kisutch*, sockeye salmon *O. nerka*, and coastal cutthroat trout *O. clarki clarki* were also recorded.

## Sample Periods

Spring sampling with the surface pair trawl was coincident with the passage of PIT-tagged yearling Chinook salmon and steelhead from the Snake River transportation study (7 March-20 August). Not all days were sampled equally. At the beginning and end of the migration season, sampling was conducted with a single shift for 2-5 d/week. As density of fish in the estuary increased, sampling increased to two daily sampling shifts (day and night shifts) for a total of approximately 12 h/d. This continued from 30 April to 14 June. As in past years, day shifts began before daylight and sampled from between 6 and 10 h, and night shifts began in late afternoon and sampled until well after dark or until relieved by the day crew. Sampling was intended to be nearly continuous throughout the daily two-shift periods except during 1400-1900 PDT, when we interrupted cruises for fueling and maintenance. This period was chosen for refueling and maintenance because of typically high winds during these hours, which slowed sampling effort significantly.

To determine the hourly diel availability of yearling Chinook salmon and steelhead, we compiled weighted hatchery and wild detection data during the 2-daily shift sampling periods. A pooled, interpolated value was used during the 5 h period between shift changes. No significant difference in diel availability associated with rearing-type was apparent; therefore, we weighted the detection data by total fish detected within each category (PTAGIS designation wild or hatchery) and plotted the hourly percentage of the total detections for each species.

In 2008, we extended cruise operations into fall (29 September-30 October) with both the matrix and shoreline systems, to sample for overwintering subyearling fall

Chinook salmon. Fall sampling was meant to be initiated when detections of fish from this group increased at Lower Granite and Bonneville Dam, indicating possible availability in the estuary. Intensity and duration of this effort depended on fish availability, but was generally conducted on alternate days during weeks sampled (Monday-Friday) with only one daily shift.

## Study Sites

We sampled primarily in the reach between Eagle Cliff (rkm 83) and the west end of Puget Island (rkm 61; Figure 1). This is a freshwater reach characterized by frequent ship traffic, occasional severe weather, and river currents often exceeding 2.5 knots. Tides in this area are semi-diurnal, with about 7 h of ebb and 4.5 h of flood. During the spring freshet period (April-June), little or no flow reversal occurs in this reach during flood tides, particularly during years of medium-to-high river flow (between 18 May and mid-June 2008, river flows were extremely high). Trawls were deployed adjacent to a 200-m-wide navigation channel, which is maintained at a depth of 14-m. The fixed-site shoreline detection system was deployed on ebb tides along Jones Beach (rkm 75).

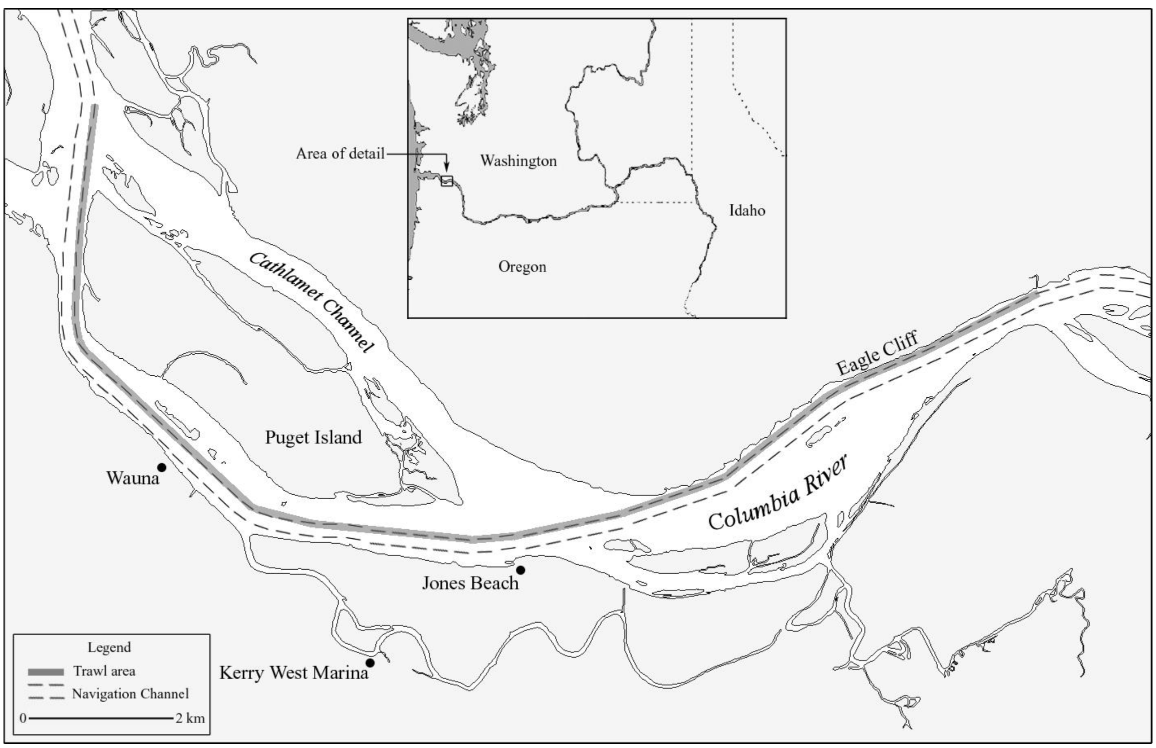



Figure 1. Trawling area adjacent to the ship navigation channel in the upper Columbia River estuary between rkm 61 and 83 and fixed-site location of shoreline sample along Jones Beach, rkm 75.

## Trawl Detection System Designs

### Cylindrical Antenna System

We began the 2008 season sampling with the same 200-kg cylindrical antenna system used in prior years (Figure 2). The cod end of a Nordic surface trawl was replaced with a cylindrical PIT-tag detection antenna system. This system had a 0.9-m-diameter fish-passage opening with a detection coil at each end of the cylinder, and with coils connected in series. This basic configuration has remained fairly constant through the years (Ledgerwood et al. 2004). To prevent turbulence on the net from the tow vessels, 73-m-long tow lines were used. The upstream end of each trawl wing was fitted with a 3-m-long spreader bar shackled to the wing section. Each wing was in turn attached to the 14-m-long trawl body and 2.7-m modified cod-end. The mouth of the trawl body opened between wings and from the surface to a depth of 6 m; a floor extended 9 m forward from the mouth. Sample depth was about 4.6 m, due to curvature in the side-walls under tow. The cylindrical antenna was 0.9 m in diameter and was centered at a depth of 1.8 m.

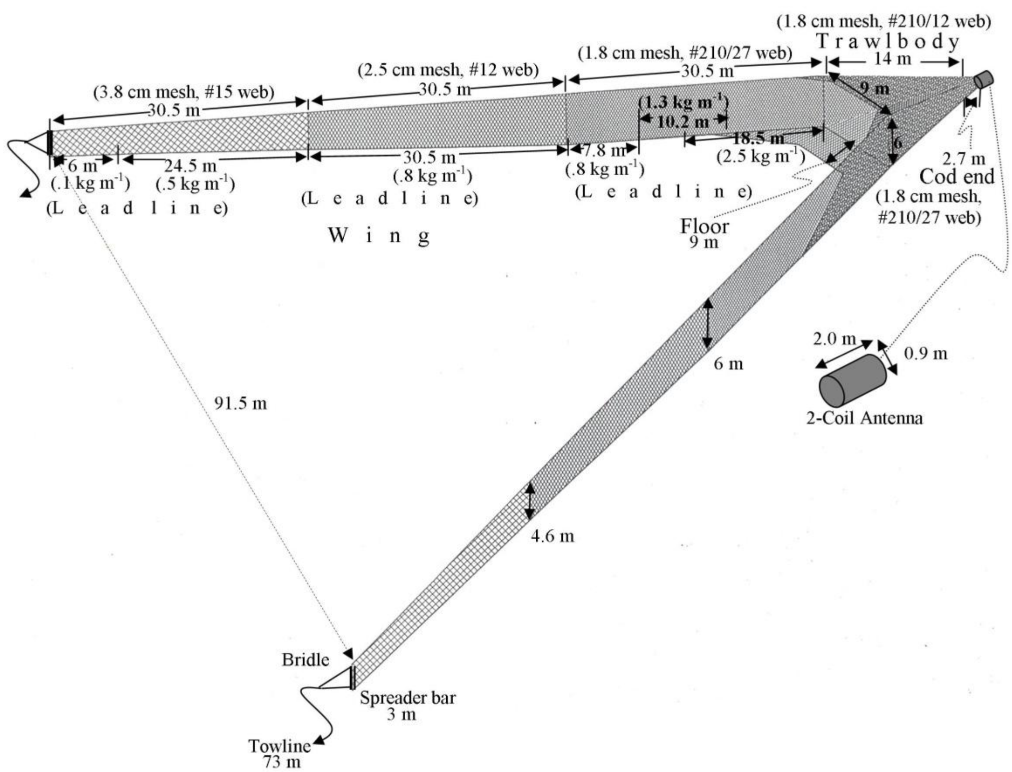



Figure 2. Basic design of the cylindrical trawl system used to sample PIT-tagged juvenile salmonids in the Columbia River estuary (rkm 75) during 2008.

During a typical deployment, the net was towed upstream facing into the current, with a distance of about 91.5 m between the trawl wings. Fish that entered between the wings were guided to the trawl body and exited through the cylindrical antenna in the cod-end. During net retrieval, the antenna was removed and the net inverted in the current to flush debris and release fish from between the trawl wings. Deployment or retrieval of the trawl required about 30 min, during which time the vessels and net were adrift in tidal and river currents often exceeding 2.5 knots.

**Matrix Antenna System**

PIT-tag technology has improved through the years, allowing for longer read ranges. Longer read ranges in the past have enabled us to configure detection antennas for a larger fish-passage opening, which has improved fish (and debris) egress from the trawl (Ledgerwood et al. 2004) and reduced drag and lift on the net, increasing the effective sample depth. In 2006, we began development of the matrix antenna trawl system, which utilized the longer read-ranges developed for PIT-tag systems (Figure 3).

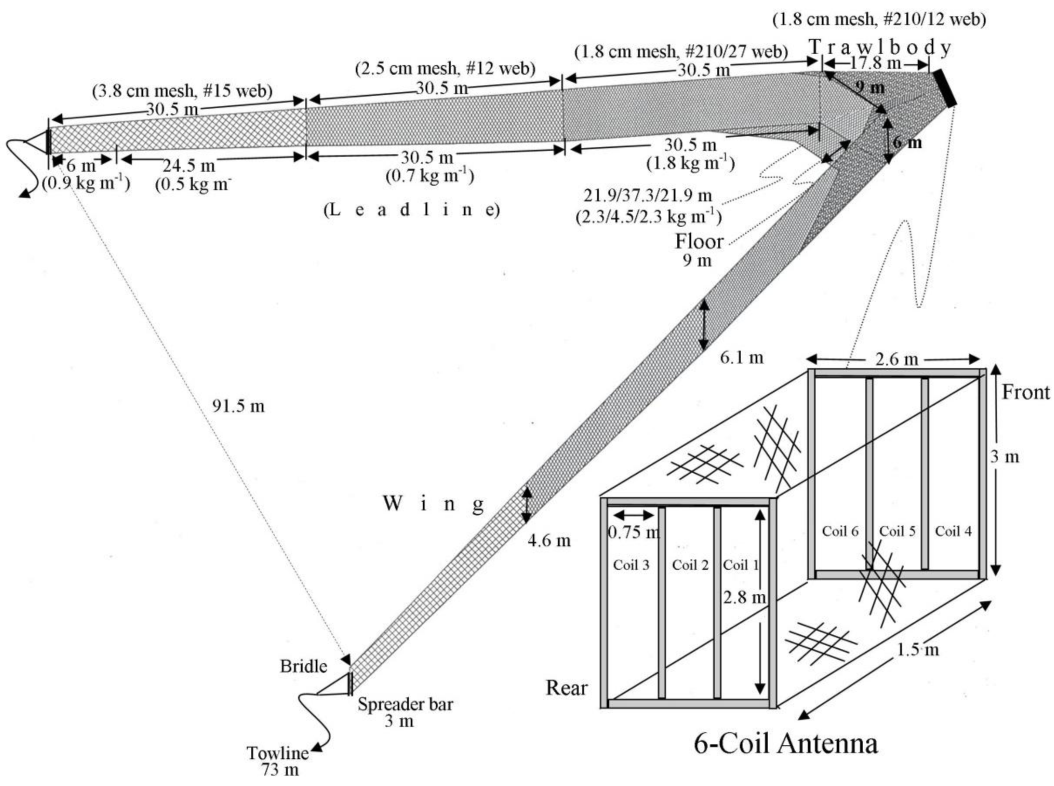



Figure 3. Basic design of the surface pair trawl used with the "matrix" antenna system to sample PIT-tagged juvenile salmonids in the Columbia River estuary (rkm 75) during May-October 2008.

The matrix system in 2008 incorporated a much larger antenna affixed to a standard size pair-trawl (trawl with same dimensions as above except where adapted to fit the larger fish passage opening).

The matrix antenna had a fish passage opening about 12 times larger than that of the cylindrical antenna and consisted of six detection coils placed in the front and rear components (3 parallel coils on each end). The front and rear components were separated by 1.5-m of net mesh, which resulted in an overall fish-passage opening 2.6 m wide by 3.0 m tall. The top of the matrix antenna was suspended 0.6 m beneath the surface on buoys and was attached to the same Nordic surface trawl used in previous years. Inside dimensions of individual coils measured $0.75 \times 2.8$ m. Each component of the matrix antenna weighed approximately 114 kg in air and required an additional 114 kg of lead weight to sink in the water column (452 kg total weight in air).

**Shoreline Detection System**

The shoreline PIT-tag detection system was configured similar to the mid-river matrix system, with a detection antenna used in place of the cod-end of a modified pair trawl (Figure 4). The shoreline system was composed of a 36.1-m-long shore-side net wing, which was anchored to a truck-mounted winch, and a 19.8-m-long offshore wing, which was attached to an anchored tow vessel with an 18.3-m line (Figure 4). Both wing sections were fixed to a 5.2-m trawl body. The trawl body opening (3.6 $m^2$ between the wings) tapered to a 2-coil matrix-style antenna, with a fish passage opening 2.6 m wide by 3.0 m tall. The antenna was suspended 0.6 m below the surface by buoys. Generally, we deployed the shoreline system near high tide and sampled during ebb currents. We used a 12.5-m-long tow vessel equipped with a net reel to deploy and retrieve the net and antenna. Current velocities varied from zero to about 1.5 knots at maximum ebb.

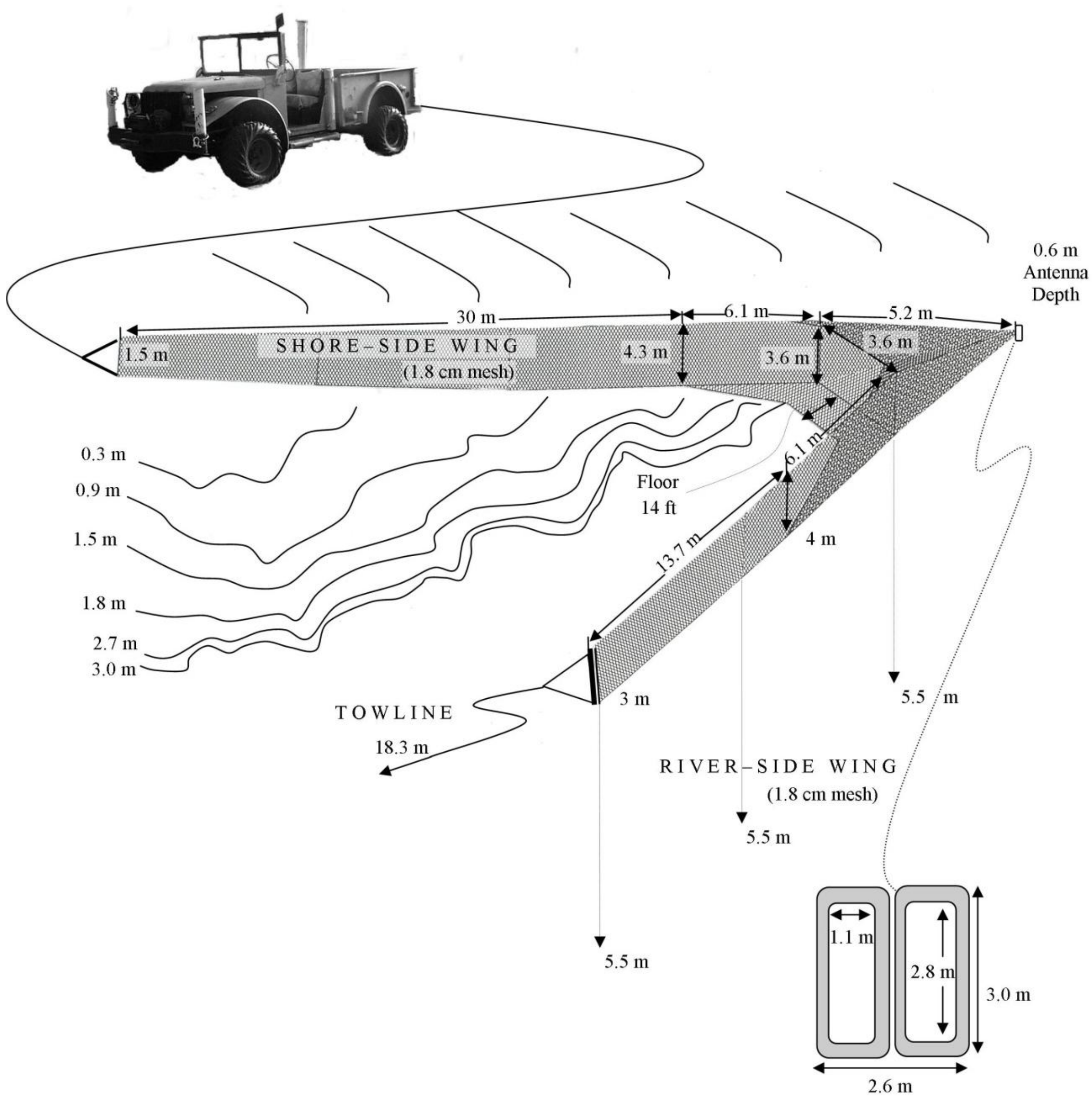



Figure 4. Design of the shoreline PIT-tag detection system used parallel to the shipping channel in the Columbia River estuary (rkm 75), 2008.

## Electronic Equipment and Operation

We used essentially the same electronic components and procedures as in 2001-2007, with the exception of the transceivers and the software. We continued to use a Digital Angel model FS1001M multiplex transceiver to power and decode data from up to six detection antennas. The transceiver and a modem were mounted in the cabin of the *RV* Electric Barge (10 m), a pontoon barge towed immediately downstream from the cylindrical antenna. The transceiver was cabled to underwater tuner ports, one on each of the two detection coils on the cylindrical system. A video camera was mounted inside the fish passage opening of the cylindrical antenna system and was used to monitor fish passage on a VCR/TV housed in the barge. A gasoline generator on the barge was used to power all electronic equipment.

Once the antenna was operating, MiniMon freeware was used to record the date, time, and tag code of each detection. MiniMon also recorded the coil identification number of the antenna that made the detection and the GPS location of the computer that recorded it. For each sampling cruise, written logs were also maintained noting the time and duration of net deployment, start and end of net flushing procedures, estimated detections per procedure, approximate location, and any incidences of impinged fish.

Electronic components for the matrix and shoreline systems were contained in a NEMA-4 rated secondary instrument box (0.8 × 0.5 × 0.3 m). For the matrix system, the secondary box was mounted on a 2.4- by 1.5-m pontoon raft; for the shoreline system, the box was mounted on a 1.9- by 1.2-m pontoon raft. Each system used a DC power source for its transceiver. Detection data were transmitted via wireless connection to a computer, which was located on shore for the shoreline system and aboard one of the tow vessels for the matrix system.

PIT-tag detection data files were periodically (about weekly) uploaded to PTAGIS using standard methods described in the *PIT-Tag Specification Document* (Stein et al. 2004). The specification document and PTAGIS operating software and user manuals are available via the Internet (PSMFC 2008). Pair-trawl detections in the PTAGIS database were identified with site code "TWX" (towed array-experimental).

Records of PIT-tagged fish detected at Bonneville Dam were downloaded from PTAGIS for comparison with our detections (PSMFC 2008). In addition, the USACE provided data on transport barge loading sites, dates, and times along with corresponding barge release dates, times, and locations (rkm). An independent database (Microsoft Access) of detection information was also maintained to facilitate data management and analyses. We modified the PTAGIS release information within our database to reflect the date, time, and river kilometer of release from transport barges.

## Detection Efficiency Tests

We used test tags attached to a vinyl-coated tape in varying configurations to evaluate electronic performance in the cylindrical, matrix, and shoreline antenna systems (Ledgerwood et al. 2005). For these tests, a 2.5-cm-diameter polyvinyl chloride (PVC) pipe was positioned through the center of each antenna coil. The pipe had a small plastic funnel on each end, and pipe ends extended at least 0.5 m past each antenna coil, beyond range of the electronic field. Detection efficiency was evaluated for both ST tags and newer SST tags. Tags were attached to identical vinyl-coated tape measures, and while each tape was passed through the pipe, we attempted to detect 16 target tags of 50 available tags at known intervals and orientations (Appendix Table 1).

Detection efficiency was evaluated for each system at the center of the antenna detection coils (Figures 5 and 6). Detection efficiency was expected to be positively correlated with improved alignment, orientation, and proximity to the electronic field. With each new trawl system design, we attempted to widen the fish-passage opening and thus increase the potential for detections. These tests were conservative by design and did not reflect actual reading efficiency for PIT-tagged fish, which generally pass in areas of the electronic field more optimal for detection.

We chose densities and orientations along the tape such that not all tags would be decoded; the relative consistency of tag detection helped validate electronic tuning and identify possible problems with the electronics. During tests, we suspended the antenna underwater and pulled the tape back and forth several times through the PVC pipe. The start time of each pass was recorded in a logbook, and we used standard PIT-tag software to record detections. Efficiency was calculated as the total number of unique tags decoded during each pass divided by the total number of tags passed through the antenna. The cylindrical antenna detection system was tested weekly, while the matrix and shoreline detection systems (very time consuming and difficult to test) were evaluated when feasible.

In 2008, we modified our analysis of detection efficiency by changing tag spacing criteria. In previous years, tag spacing was based on the distance of the following tag on the test tape as the tape passed through the antenna. Under the new criteria, tags included for analysis were only those that had a tag preceding and a tag following, where each tag was separated by an equal interval, regardless of tag orientation or tape direction.

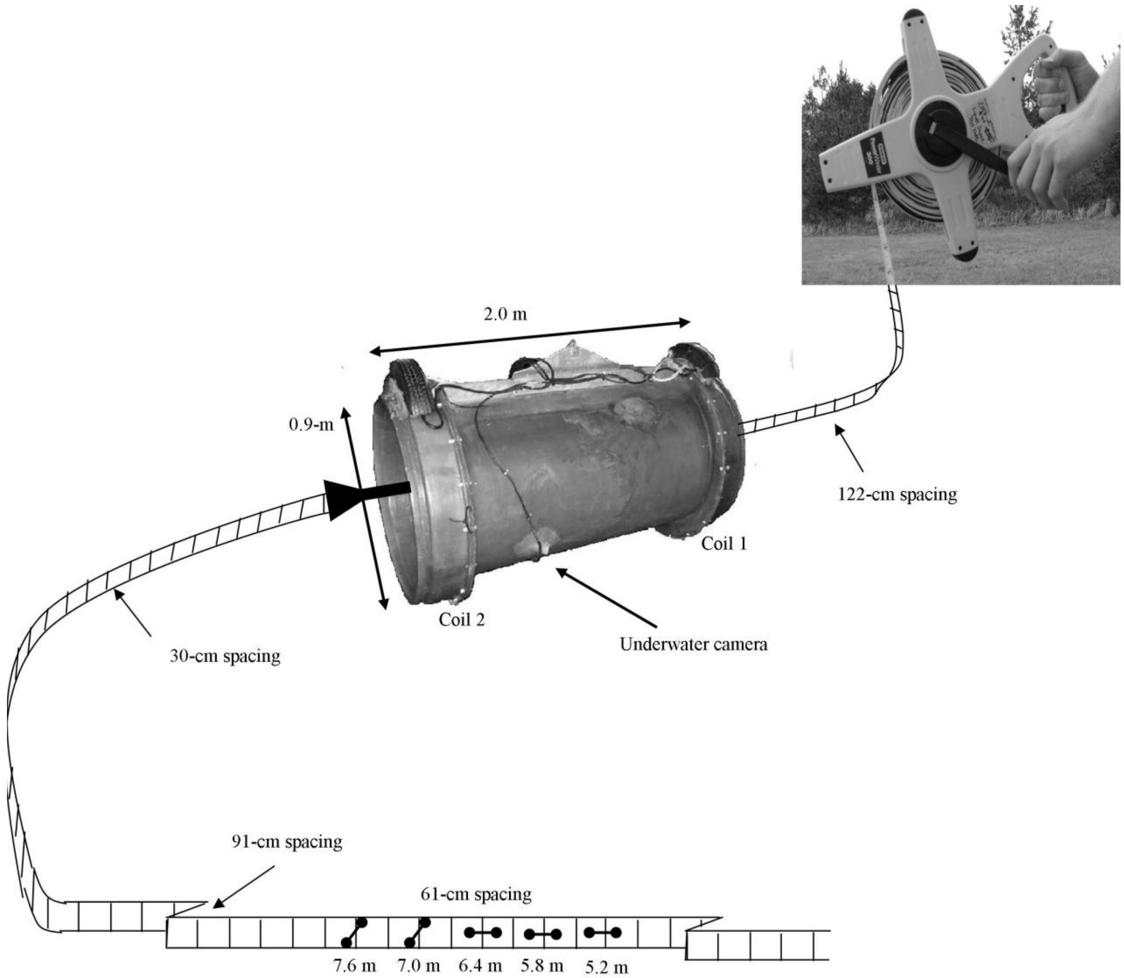



Figure 5. Funnel testing system depicting test tag laden vinyl tape measure, threaded through a PVC pipe positioned in the center of the two-coil cylindrical antenna. PIT-tags were oriented at 0 and 45 degrees to the direction of travel and spaced at 30, 61, 91, and 122 cm.

Intervals tested were 30, 61, and 91 cm, and an interval code was assigned to each respective tag. Tags that fit the test criteria were designated "target tags" for analysis, and all other tags were excluded. Thus, test data on read efficiency collected during 2008 required substantial culling compared to previous years, and not all spacing was equally represented. Additionally, because our methodology for this analysis has changed, comparisons of detection efficiency to previous years are inappropriate. A new, more robust test-tape configuration, with equal tag representation of spacing and orientation, is now available.

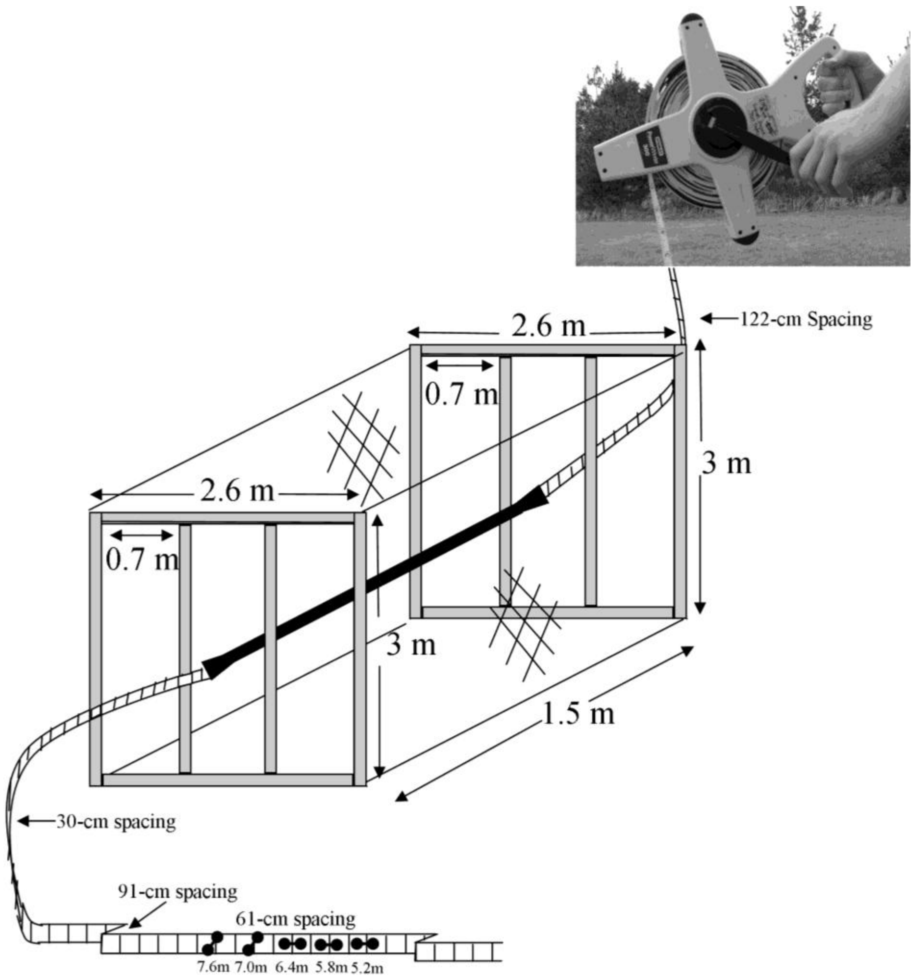



Figure 6. Sketch depicting the funnel testing system with vinyl tape loaded with tags and threaded through a PVC pipe. For both the front and rear components, we positioned the pipe in the center the middle antenna coil. PIT-tags were oriented at 0 and 45 degrees to the direction of travel and spaced at 30, 61, 91, and 122 cm.

## Antenna Detection Efficiency

Through the years of study, changes in sampling locations, PIT-tag technology, and associated electronic equipment enabled us to develop new antennas with larger fish passage openings (cylindrical, matrix, and shoreline antennas). However, in 2007, the cylindrical antenna used in 2006 (1.1 m diameter) developed a leak and tested poorly. This forced a return in 2007 to the smaller antenna used during 2000-2005 (0.9 m diameter), and we began the 2008 season with this smaller antenna.

During this time, we continued development and testing of the much larger matrix antenna system. Efficiencies of each system were evaluated using test tags on a tape measure as described above. Detection rates obtained during testing were compared to tests with previous antenna designs to help measure the overall efficiency of new designs and to indicate areas where modification or tuning was needed.

## Comparative System Passage Efficiency

Initial testing of the matrix antenna system was conducted in 2006-2007. However, to compare relative passage efficiency, we needed to deploy both the cylindrical and matrix systems simultaneously. In 2006, the matrix system had been composed of only two antenna coils and used with a smaller trawl. In 2007, the small trawl was replaced with a full-sized trawl, and a picking davit was installed on the stern of one 12.5-m tow vessel. This allowed safe deployment of a larger matrix antenna and enabled us to develop of operational logistics for routine sampling (Magie et.a1 2009).

Testing in spring 2007 proved satisfactory, and during the off-season, we modified a second tow vessel to handle the matrix system for backup and for simultaneous testing with the cylindrical system. Simultaneous tests were conducted in May 2008 during a period of relatively high densities of PIT-tagged fish. We also constructed new trawl bodies that matched the dimensions of the matrix antenna system. This allowed quick conversion from the older cylindrical system to the new matrix system. We were prepared to shift all sampling effort to exclusive use of the matrix system if simultaneous sampling revealed higher detection rates in that system with no negative impacts to fish.

We also evaluated system passage efficiency between the cylindrical and matrix systems by comparing detections obtained during their respective “open” and “flush” periods. During the 19-min open periods, the wings of the trawl were fully open and separated by a distance of 91 m, and this maximized fish collection in the trawl. During the 5-min flush periods, the trawl wings are brought together until parallel with the outside edges of the trawl body. Flushing was conducted to encourage the exit of fish that had accumulated in the trawl and were pacing the net sections instead of passing through the antenna system exit. Flushing produces a slightly higher water velocity through the system, with a change in net configuration, and loss of orientation for fish. Fish detection rates during each of these open/flush periods were compared for cylindrical and matrix systems during their respective two-shift deployment periods. We anticipated higher rates of passage during the open periods with the matrix antenna system due to a greater volume of water passing through its larger fish passage opening.

## Impacts to Fish

We used video to monitor debris accumulation in the antenna and in the cod end of the net. Other sections of the net were monitored visually, and accumulated debris was removed from all net sections as necessary. We adjusted sample operations accordingly upon any indication of impacts to fish. When debris accumulated, we reduced tow speed and pulled the antenna to the surface to remove entrained material through surface zippers in the cod end. During conditions of extreme debris loading, we disconnected the electronics and inverted the entire net for cleaning.

The matrix antenna was not removed from the trawl net during retrieval, as with the cylindrical antenna, but retrieved directly onto a tow vessel with the net still attached. Since the net was never inverted using the matrix system, debris could potentially accumulate in the net, with subsequent impacts to fish passing through the trawl body. The larger fish passage opening of the matrix antenna did allow more debris to pass out of the system and resulted in an overall reduction of debris accumulation. However, some debris had to be removed by hand, either through zippers in the top of the trawl body during retrieval, which required longer drifts, or back at the dock. For both systems, we recorded any impinged or trapped fish seen during debris-removal activities or net hauling and redeployment. These fish were recorded as mortalities in the operation log books.

## Data Analyses

### Diel Detection Rates

To determine diel availability of yearling Chinook salmon and steelhead during the two-shift sampling period, we compiled hourly detection data and weighted the data by hatchery or wild source. A smoothed, interpolated value was used during the afternoon period between shifts, when sample effort was halted. We found no significant difference in diel availability between rearing types. Therefore, we weighted the detection data by total fish within each category (daylight or darkness hour).

Numbers of yearling Chinook salmon and steelhead detected per hour of daylight and per hour of darkness were evaluated using one-way ANOVA-unstacked (Zar 1999). The number of detections and the minutes within each hour of the day that the detector was operating were separated into daylight- and darkness-hour categories. Preliminary analyses and hourly detection rates were pooled for wild and hatchery rearing types of each species for each category. These mean hourly detection rates were compared statistically, and diel detection curves were compiled for yearling Chinook salmon and steelhead weighted by the number of minutes within each hour that the detector was operating. There were insufficient detections of other species for meaningful analyses.

### Travel Time

We plotted travel-time distributions and compared detection rates of yearling Chinook salmon and steelhead released at Lower Granite Dam. Fish of both species detected in the estuary had histories of either inriver migration with detection at Bonneville Dam or transport to a release site downstream from Bonneville Dam (with prior detection on transport-barge loading raceways). For subyearling Chinook salmon, similar evaluations were conducted, with travel time distributions plotted for fish that were transported vs. released inriver to migrate during late June-July. These plots represented seasonal presence in the estuary of the respective fish groups.

Data from periods of availability in the estuary for the various subsets of fish were compared using analyses of travel-time distributions. Travel time to the estuary was calculated for each fish by subtracting date and time of barge release or detection at Bonneville Dam from date and time of estuary detection.

One-way ANOVA was also used to evaluate differences in travel speed to Jones Beach between inriver migrants and transported fish. Daily median travel speeds ($km\ d^{-1}$) were calculated for yearling Chinook salmon, steelhead, and subyearling Chinook salmon. Travel speed was based on the travel time divided by the distance traveled from release to detection in the estuary and plotted over the periods of availability for each respective species. Travel time data were compared with daily average discharge rates at Bonneville Dam ($m^3$ $s^{-1}$) during the same periods.

**Detection Rates and Migration History**

Estuarine detection rates of smolts released from barges vs. those previously detected in the juvenile bypass system at Bonneville Dam (inriver migrants) were compared using logistic regression analysis (Hosmer and Lemeshow 2000; Ryan et al. 2003). Inriver migrants detected at Bonneville Dam were grouped by date of detection and paired with transported fish released from a barge on the same date. These comparisons included only fish that were PIT-tagged and released upstream from McNary Dam. Fish from barges released just after midnight were paired with fish detected at Bonneville Dam the previous day.

Fish transported early in the migration season were often released below Bonneville Dam before sufficient numbers of inriver migrant fish had arrived at the dam. Recovery percentages for the overall season are shown for both inriver and transported fish groups; however, daily groups were not used for comparative analysis unless both groups were present and detected during intensive two-shift sampling periods.

We used the same logistic regression analysis to compare estuarine detection rates between fish transported from different locations. Due to data constraints, we compared fish transported from Lower Granite Dam to those from Little Goose and Lower Monumental Dams combined. Date and date-squared were also considered in the model. Components of the logistic regression model were treatment as a factor and date and date-squared as covariates. The model estimated the log odds of detection for *i* daily cohorts (i.e., ln [$p_i/(1 - p_i)$]) as a linear function of components, assuming a binomial distribution for the errors.

Daily detection rates were then estimated as:

$$\widehat{p}_i = \frac{e^{\widehat{\beta}_0 + \widehat{\beta}_1 day_i + \widehat{\beta} X_i}}{1 + e^{\widehat{\beta}_0 + \widehat{\beta}_1 day_i + \widehat{\beta} X_i}}$$

where β is the coefficient of the components (i.e., 0 for the intercept, 1 for day *i*, and *X* for the set "$X_i$" day-squared and/or interaction terms). We used a stepwise procedure to determine the appropriate model.

First, the model containing interactions between treatment and date and date-squared was fitted. Second, we determined the amount of overdispersion in the data relative to the binomial distribution assumption (Ramsey and Schafer 1997).

Overdispersion was estimated as σ, the square root of the model deviance statistic divided by the degrees of freedom. If σ was greater than 1.0, we adjusted the standard errors of the model coefficients by multiplying by σ (Ramsey and Schafer 1997). This inversely adjusted the *z* statistic used to test the significance of the coefficients. Third, if the interaction terms were not statistically significant (likelihood ration test $\alpha > 0.05$) the term were removed and a reduced model was fitted. The model was further reduced depending on the significance between treatment and date and/or date-squared. The final model was the most simplified from this process.

Various diagnostic plots were examined to assess the appropriateness of the models. Extreme or highly influential data points were identified and included or excluded on an individual basis, depending on context.

The daily transported and inriver migrant groups had similar distributions in the sampling area and presumably passed the sample area at similar times. Thus, we assumed these groups were subject to the same sampling biases (sample effort). If these assumptions are correct, then differences in the relative detection rates will reflect real differences in survival to the estuary between inriver migrant groups detected at Bonneville Dam and transport groups released just below the dam.

We examined the assumption that barged and inriver migrant groups passed the sample area with similar diel timing using total seasonal detections. Individual detections were binned into interval hours based on time of detection. Diel detection curves were prepared for yearling Chinook salmon and steelhead based on the average number of fish detected each hour weighted by the number of minutes within each hour that the detectors were energized. (Detections of other salmonid species were insufficient for this analysis.) Differences in the average hourly detection rate between transported and inriver migrant groups were then plotted by species. Data from study years 2000 to 2007 were examined to provide an overview of differences between and among years.

**Downstream Passage Survival**

Detection data from the estuary are essential for estimates of survival through Bonneville Dam, the last dam encountered by juvenile salmon migrants (Muir et al. 2001; Williams et al. 2001; Zabel et al. 2002). Survival probability is estimated from PIT-tag detection data using a multiple-recapture model for single release groups (CJS model; Cormack 1964; Jolly 1965; Seber 1965; Skalski et al. 1998). This model requires detection probability estimates, which in turn require detection or recapture data obtained downstream from the lowest point of interest or reach for which survival estimates are wanted (i.e., Bonneville Dam). At present, trawl detections are the only source of this recapture data.

# RESULTS

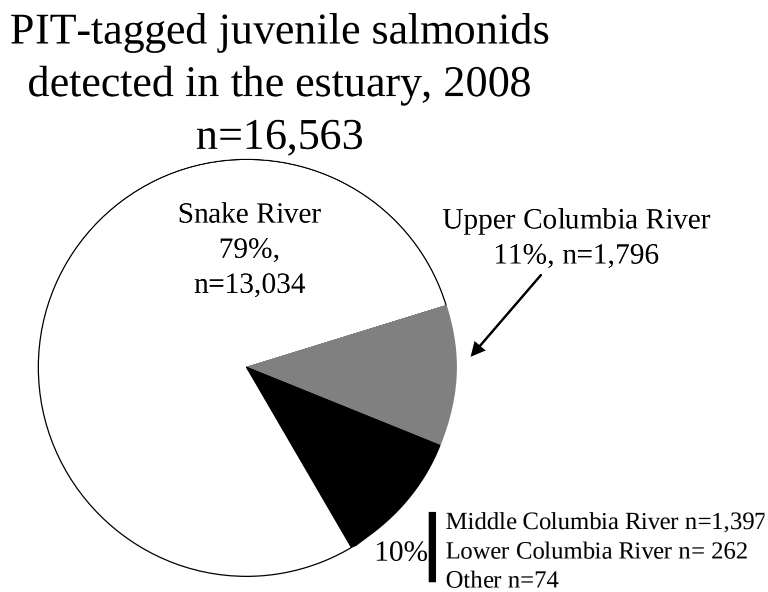
## Trawl System Detections

In 2008, we detected 16,563 PIT-tagged juvenile salmonids of various species, runs, and rearing types, using both the cylindrical and matrix detection systems (Table 1; Appendix Table 2). Species and rearing types were detected in the trawl in various proportions, which were not necessarily representative of their respective abundances in the estuary. For example, 61% of our detections were Chinook salmon, 36% were steelhead, and the remaining 3% were other salmonid species (Table 1). Among detections of all species combined, 16% were wild, 81% hatchery, and 3% were of unknown origin. River basin source and migration history for PIT-tagged fish detected in the estuary are shown in Figure 7. Annual differences in PIT-tagging strategies, hydrosystem operations, and the number of fish transported contributed to variation in the proportions detected from each source.

Table 1. Species composition and rearing history of PIT-tagged fish detected with the cylindrical and matrix antenna trawl systems in the upper Columbia River estuary near rkm 75 in 2008.

| | Rear Type | | | |
|---|---|---|---|---|
| Species/run | Hatchery | Wild | Unknown | Total |
| Spring/summer Chinook salmon | 6,171 | 175 | 1,051 | 7,397 |
| Fall Chinook salmon | 2,657 | 39 | 39 | 2,735 |
| Coho salmon | 287 | 0 | 4 | 291 |
| Steelhead | 4,205 | 165 | 1,580 | 5,950 |
| Sockeye | 87 | 0 | 35 | 122 |
| Sea-run Cutthroat trout | 0 | 0 | 0 | 0 |
| Unknown | 0 | 0 | 68 | 68 |
| Grand total | 13,407 | 379 | 2,777 | 16,563 |

During the spring/summer 2008 migration period, we sampled with the cylindrical antenna detection system for 202 h and the matrix antenna detection system for 774 h, for a total deployment time of 976 h. We detected 16,560 fish during 976 h of deployment; by comparison, in 2007 we detected 19,186 fish during 1,059 h of deployment (Figure 8). Fewer fish were detected per hour in 2008 than in 2007 (16 vs. 18 fish/h), despite the release of about 39% more PIT-tagged fish in 2008 than in 2007 (PTAGIS).



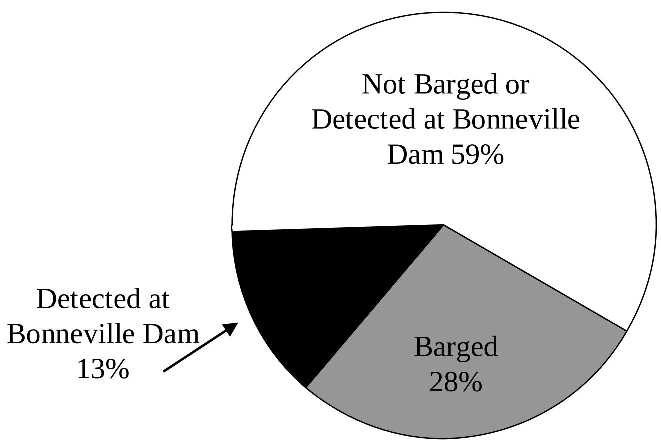




Figure 7. River basin sources and migration histories of PIT-tagged fish detected in the Columbia River estuary near rkm 75, 2008. Upper and mid-Columbia River here indicates reaches upstream from McNary Dam. Both categories have potential to be detected passing Bonneville Dam, unlike lower Columbia River releases. Only upper-Columbia and Snake River categories have the potential to be transported.

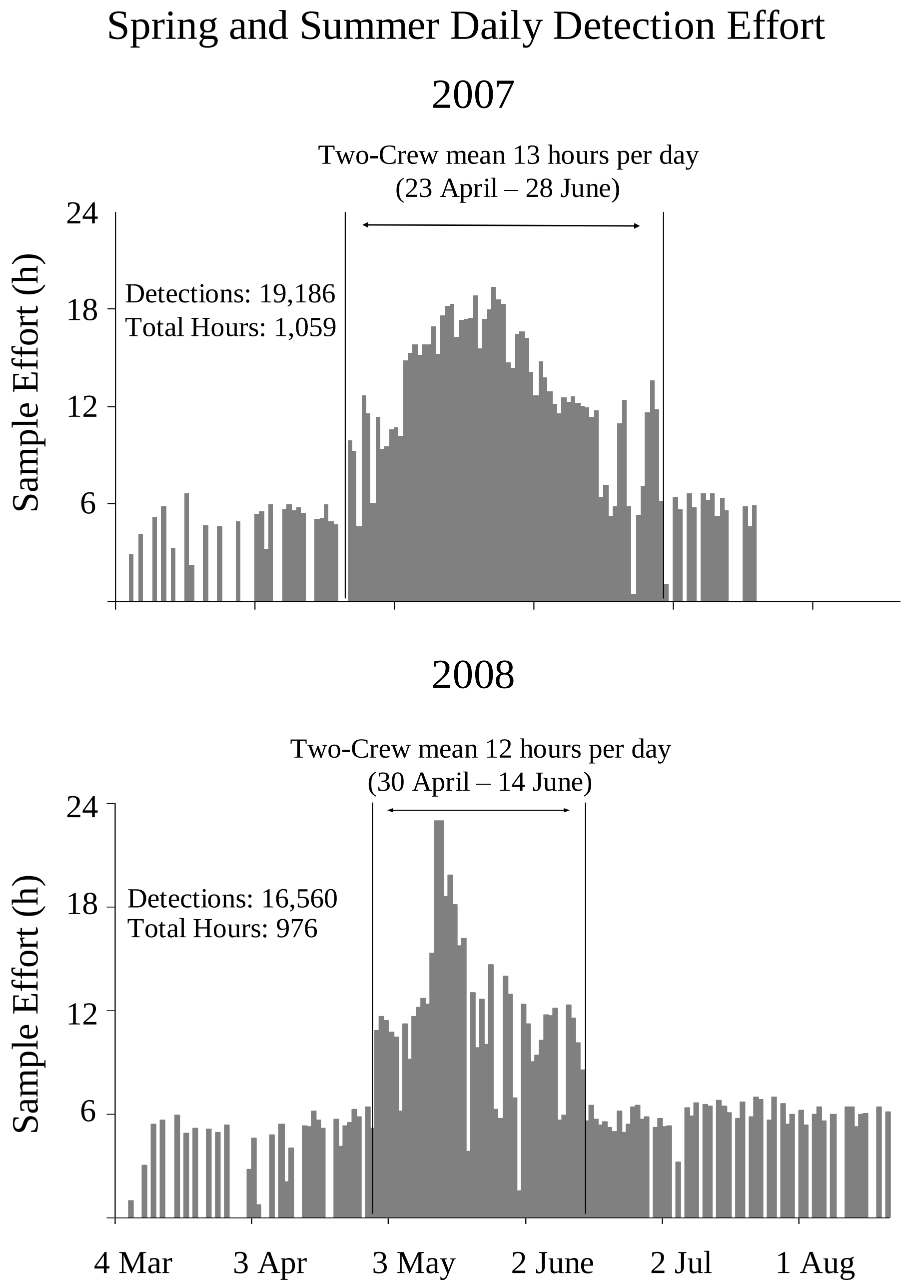



Figure 8. Daily sample effort during the spring and summer using the cylindrical and matrix antenna PIT-tag detection systems near river kilometer 75, 2007-2008.

Uncharacteristically high river flows after 18 May contributed dramatically to the lower numbers of fish detected in 2008. Because of the high flows, we began sampling further upstream in the reach than usual. The high flows also contributed to heavy debris loads, which reduced daily sampling time and in some cases caused the cancellation of entire sampling shifts. Detection rates at Bonneville Dam were also affected by debris loads that required the removal of fish guidance screens during a flood from 19 May to 13 June (Table 2). Without the screens in place, fish could not be diverted through the juvenile fish facility (JFF); considerably fewer fish were detected in the JFF during this time.

Table2. Detections of juvenile Chinook salmon and steelhead at Bonneville Dam before and during a flood event within the two-shift sampling period in 2008.

| Bonneville observation site | 28 April-19 May (typical flow) 22 d | | | | 19 May-13 June (flood) 26 d | | | |
|---|---|---|---|---|---|---|---|---|
| | Chinook | | Steelhead | | Chinook | | Steelhead | |
| | n | (%) | n | (%) | n | (%) | n | (%) |
| Juvenile facility | 16,796 | 56.13 | 3,236 | 16.35 | 4,453 | 27.62 | 1,232 | 15.12 |
| Corner collect | 13,128 | 43.87 | 16,550 | 83.65 | 11,669 | 72.38 | 6,915 | 84.88 |

During our two-crew sample period and before the high flow event, almost 60% of the Chinook salmon detected at Bonneville Dam had passed via the JFF, and roughly 40% had passed through the corner collector. During the high flow event, the proportion of Chinook salmon in the JFF dropped to about 30% of the daily total with a corresponding increase to about 70% through the corner collector. Because spill was also increased during this period to pass excess water at Bonneville Dam, an unusually high number of Chinook salmon would have passed via this route, where no PIT-tag detections were possible. Steelhead proportions remained relatively consistent both before and after the flood event with approximately 80% passage through the corner collector and about 20% passage through the JFF.

Mean flow volumes in the Columbia River were about 27% higher during the two-shift sampling period in 2008 than during the two-shift period in 2007 (9,516 $m^3\ s^{-1}$ vs. 6,934 $m^3\ s^{-1}$; Figure 9). Lower-than-average flows tend to slow migration speeds and dispersion of groups, thus extending the period of availability in the sample reach. Pair-trawl sampling conducted at rkm 75 since 1998 has revealed a strong correlation between high flows and lower detection rates of PIT-tagged fish.

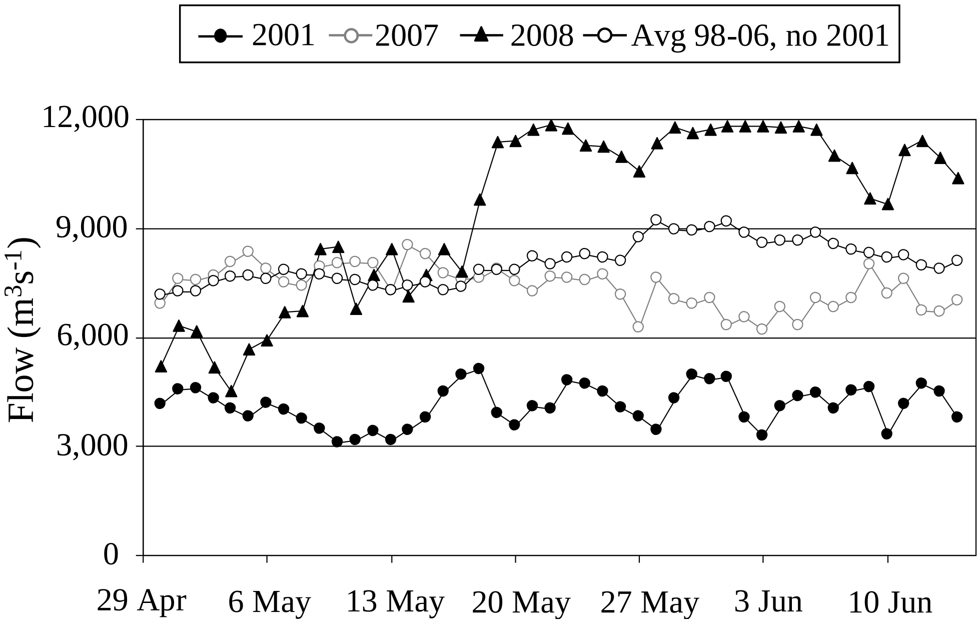



Figure 9. Columbia River flows at Bonneville Dam during the two-shift sample periods in 2007 and 2008 as compared to the average flows from 1998 to 2006. Drought-year flows for 2001 are also shown for comparison.

Sampling was conducted in fall 2008 to determine the availability of subyearling fall Chinook salmon in the estuary. Sampling with both the matrix and shoreline antenna systems was initiated when water temperatures were decreasing; however, during the fall sample period, no notable increase in PIT-tag detections was seen at Bonneville Dam (initial indicator to sample). The shoreline sampling system was deployed at rkm 75 on 5 cruises between 29 September and 30 October for a total of 24 h (1 fish was detected). Target fish were juvenile salmonids in the shallow, near-shore waters of the estuary; these areas are inaccessible to the larger mid-river trawl system. These shoreline locations were of interest because of their potential to provide rearing areas and shelter. The matrix system was deployed during the same period on six cruises for a total deployment time of 35 h (2 fish detected; Table 3).

Table 3. PIT-tag detections during fall sampling (29 September-30 October) by matrix and shoreline antenna systems at rkm 75, 2008.

| Sample date | Sample method | Tag ID | Species | Tag Site | Release Date |
|---|---|---|---|---|---|
| 10/14/08 | Matrix | 3D9.1C2CBC1DD9 | Fall Chinook | LWSH | 7/3/08 |
| 10/15/08 | Shoreline | 3D9.1C2C4DB46E | Chinook* | LGR | 10/10/2008 |
| 10/27/08 | Matrix | 3D9.1C2D03D406 | Spring Chinook | MCKER | 9/2/2008 |

* Unknown run code in PTAGIS

## Electronic Performance and Efficiency Evaluations

### Spacing and Orientation Effects on Detection Efficiency

Tape tests showed that test tags oriented perpendicular to the electronic field were read at higher rates than those placed at an angle. Efficiencies were also positively correlated with spacing between tags, regardless of orientation. It is important to note that these differences in detection efficiencies were often observable only when the tape was passed through the center of the antenna. When tapes were passed near the edge of the antenna (the optimal detection area and where most fish pass), tag orientation made little difference in reading efficiency.

According to PTAGIS, about 88% of the PIT-tagged fish released into the basin for migration in 2008 were tagged with the newer SST tags, which have longer read ranges than the older ST tags. About 84% of detections in 2008 were SST tags, and the remaining were ST tags. The enlarged passage opening of the matrix antenna was designed based on the increased read ranges possible with SST tags. However, because transition to the newer SST tags was not yet complete in 2008, detection efficiency tests were conducted using both the ST and SST tags.

The 6-coil matrix antenna read neither the ST nor the SST test tags when tags were spaced 30 cm apart (nearest spacing tested) and held perpendicular to the electronic field (Figure 9). When tag spacing was increased to 61 cm, detection efficiency for perpendicular tags increased to nearly 88 and 90% for ST and SST tags, respectively. For tags spaced 61 cm apart and placed at 45° angles, efficiency was 83% for ST tags and 63% for SST tags. At a tag spacing of 91 cm, detection efficiencies were 100% for perpendicular tags, regardless of tag type. Detection efficiency of the matrix antenna for tags spaced 91 cm apart and oriented at 45 degrees was 90% for ST tags and 100% for SST tags.

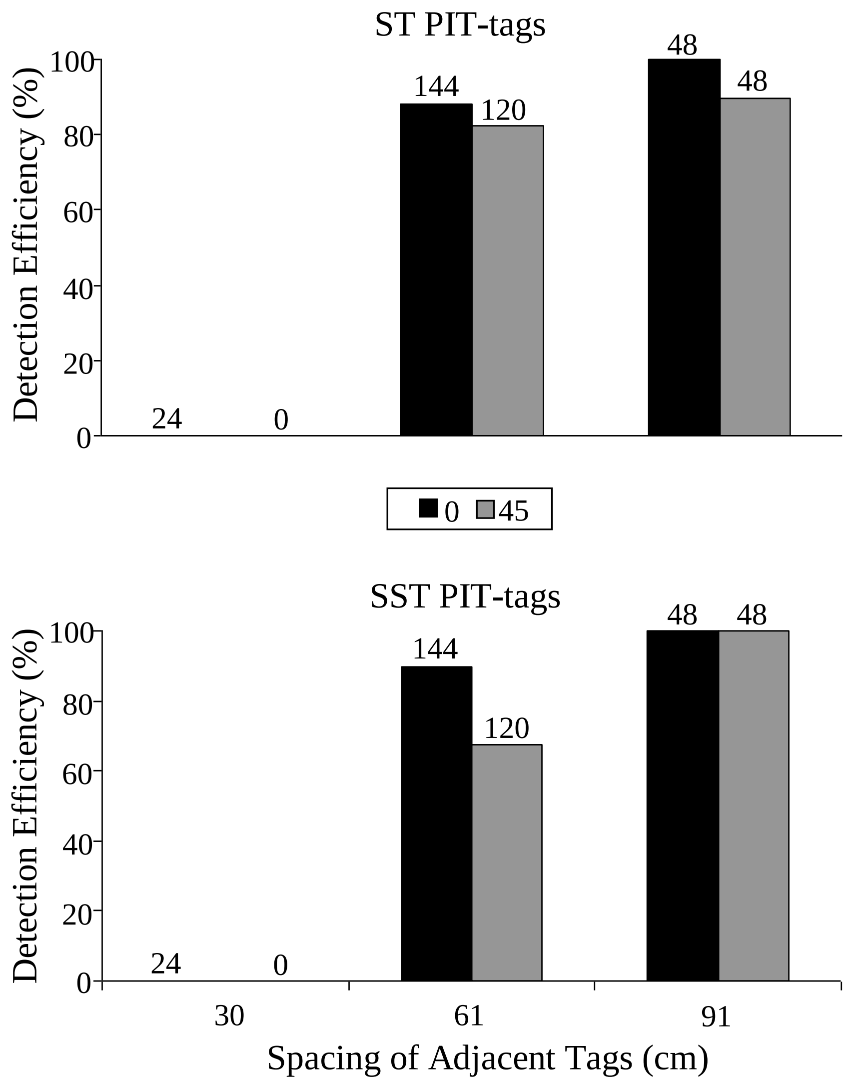



Figure 9. Read efficiency of 6-coil matrix antenna determined by targeting 16 target PIT tags from an available 50 attached to vinyl tape measures, 2008. Various spacing between tags, orientations, and tag types (ST vs. SST) in the electronic field were used. Tags were passed through the antenna repeatedly on different dates (total potential tags listed above the bars).

## Antenna Efficiency

Antenna efficiency was based on the pooled reading rates of test tapes (all spaces and orientations of 16 target tags) evaluated for each antenna and individual antenna coil through the season. The 0.9-m-diameter cylindrical antenna system used at the beginning of 2008 had higher detection rates of both ST and SST tags than either the 2-coil or the 6-coil matrix antenna (Table 4). Antenna efficiency of the 2-coil shoreline matrix antenna was lower than all other antennas (74% for ST and 66% for SST tags), while antenna efficiency of the 6-coil matrix antenna fell in the middle (83% for ST and 80% for SST tags).

Higher reading efficiencies were expected for the SST tags because of their increased read ranges; however, all three antennas read ST tags more efficiently. We considered that the increased reading range of SST tags may have also increased the occurrence of tag collision. Tag collision occurs when two or more tags are in the detection field simultaneously, and neither tag is decoded. To reduce tag collision, we reduced field size of the matrix antenna, and tried to do so without reducing field strength. This improved consistency in reading tags spaced 61 and 91 cm apart and allowed the matrix antenna system to read tags spaced at 30-cm intervals. Problems with tag collisions are not expected at most interrogation sites. However, fish tend to pass through the trawl system antennas at higher densities; thus, tag collision may be more common in the trawl system than at other interrogation sites.

Table 4. Detection efficiencies of three PIT-tag antenna designs used in 2008. Efficiencies for the cylindrical antenna were determined using average read rate of 16 target tags tested on vinyl tape at various spacing and orientation. The 6-coil matrix and 2-coil shoreline antenna were also tested using the vinyl tape.

| Antenna (dimensions) | Tag type | Total target tags* (N) | Overall antenna efficiency (center %) | Maximum antenna efficiency (center %) | Maximum antenna efficiency (side %) |
|---|---|---|---|---|---|
| Cylindrical (0.9-m diameter) | ST | 1,024 | 92 | 94 | 97 |
| Cylindrical (0.9-m diameter) | SST | 128 | 85 | 91 | 91 |
| Matrix (1.1- × 2.8-m perimeter) | ST | 128 | 74 | 88 | N/A |
| Matrix (1.1- × 2.8-m perimeter) | SST | 128 | 66 | 75 | N/A |
| Matrix (0.7- × 2.8-m perimeter) | ST | 384 | 83 | 94 | N/A |
| Matrix (0.7- × 2.8-m perimeter) | SST | 384 | 80 | 94 | N/A |

* Sixteen target tags selected have identical spacing and orientation in both directions for multiple tape passes through the antenna.

As with previous antennas, we evaluated matrix antenna performance daily by comparing the total number of fish detected to the number detected on individual coils, all front coils, and all rear coils (Figure 10). A two-component antenna system provides a second chance to decode tagged fish on a rear component missed by coils on the front component. When the proportion of fish detected on an individual coil was significantly less than for other coils, a problem was indicated. It should be noted that antenna coils of the front component normally had more detection records and unique fish detections than those of the rear component. Some fish approached the front component, were detected, and then moved upstream only to approach and be detected again. Of these fish, some likely escaped the trawl after moving upstream and were never detected on the rear coil.

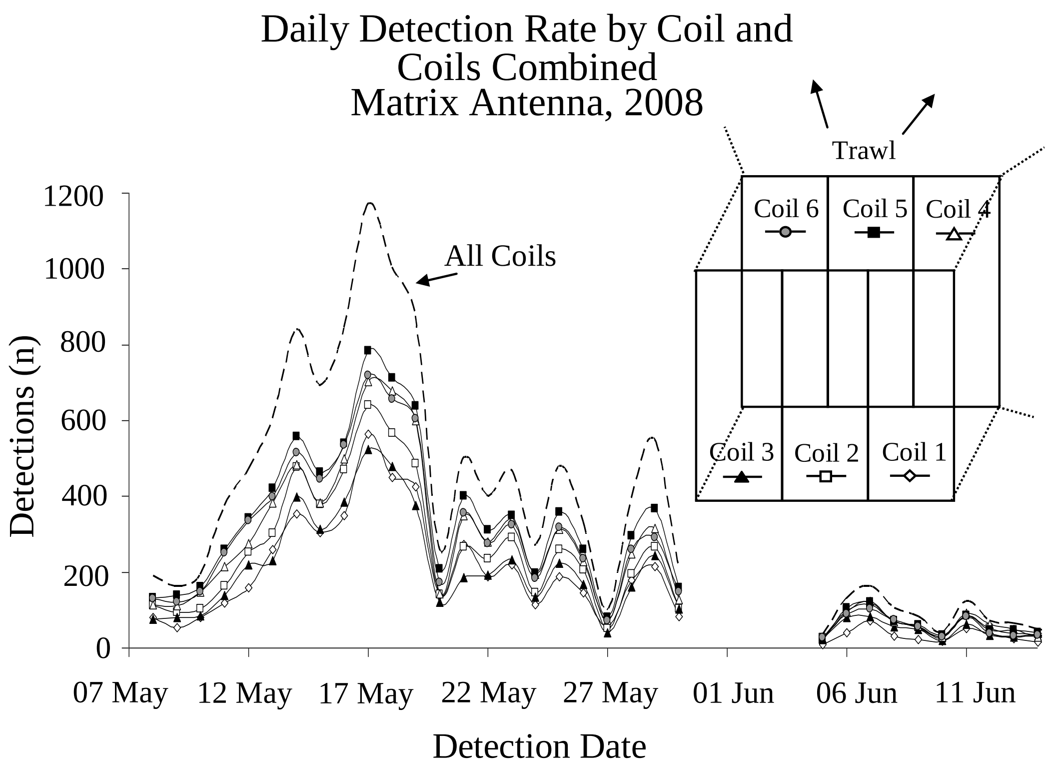



Figure 10. Daily detections of juvenile salmonids by coil using the matrix antenna system during the two-shift sample period, 2008. Coils 1-3 form the rear component while coils 4-6 make up the front component closest to the trawl. Data gap reflects the use of the 5-coil backup antenna.

## Comparative System Passage Efficiency

Simultaneous testing of two full-sized pair trawls required four 12.5-m tow vessels. However, we had only three 12.5-m vessels, so we substituted a pair of 7.9-m gas-powered vessels arranged in tandem to tow one of the four trawl wings. During simultaneous testing, we towed the matrix antenna system using the tandem vessels and one 12.5-m tow vessel, which was equipped with a net reel. The 12.5-m tow vessels were maintained at normal power (1,100 rpm) and the tandem vessels matched their speed. This configuration was successful in that both detection systems traveled at almost identical speeds and remained within 1 km of each other during most simultaneous deployments.

On 13, 14, and 15 May, both the cylindrical and matrix systems were deployed during day shifts (Figure 11). Generally, the cylindrical antenna crew would depart and deploy their system about one hour prior to departure/deployment of the matrix system. The matrix system was deployed slightly upstream from the cylindrical system on day 1 and downstream from it on days 2 and 3. The goal was to sample as close to each other as possible. Net flushing times were synchronized between the two systems, and detection numbers recorded on both systems in our standard procedure. A total of 1,055 PIT-tagged fish were detected during simultaneous sample periods, and 76 of these were detected on both systems. Median travel time between systems was 23.6 min (Appendix Table 3).

During 14.5 h of simultaneous sampling, the cylindrical antenna system detected 339 fish and the matrix system detected 716 (a 111% increase). Moreover, the higher rates of detection with the matrix system were consistent, as the cylindrical system detected more fish than the matrix system in only 3 of 34 simultaneous net flushes. Deployment and retrieval procedures were also simplified and safer (no net inversion or antenna removal) using the matrix system. Therefore, after the third day of simultaneous sampling on 15 May, the cylindrical antenna and related equipment were retired, and we continued sampling exclusively with the matrix system.

Fish passage efficiency was also evaluated between the cylindrical and matrix systems by comparing rates of passage during open and flush periods while deployed during the two-shift sampling effort. Although both systems exhibited higher rates of passage during flush periods than during open periods, a comparison between systems showed a significantly higher rate of passage during open periods in the matrix than in the cylindrical system for both Chinook salmon ($P = 0.0005$) and steelhead ($P = 0.01$; Table 5).

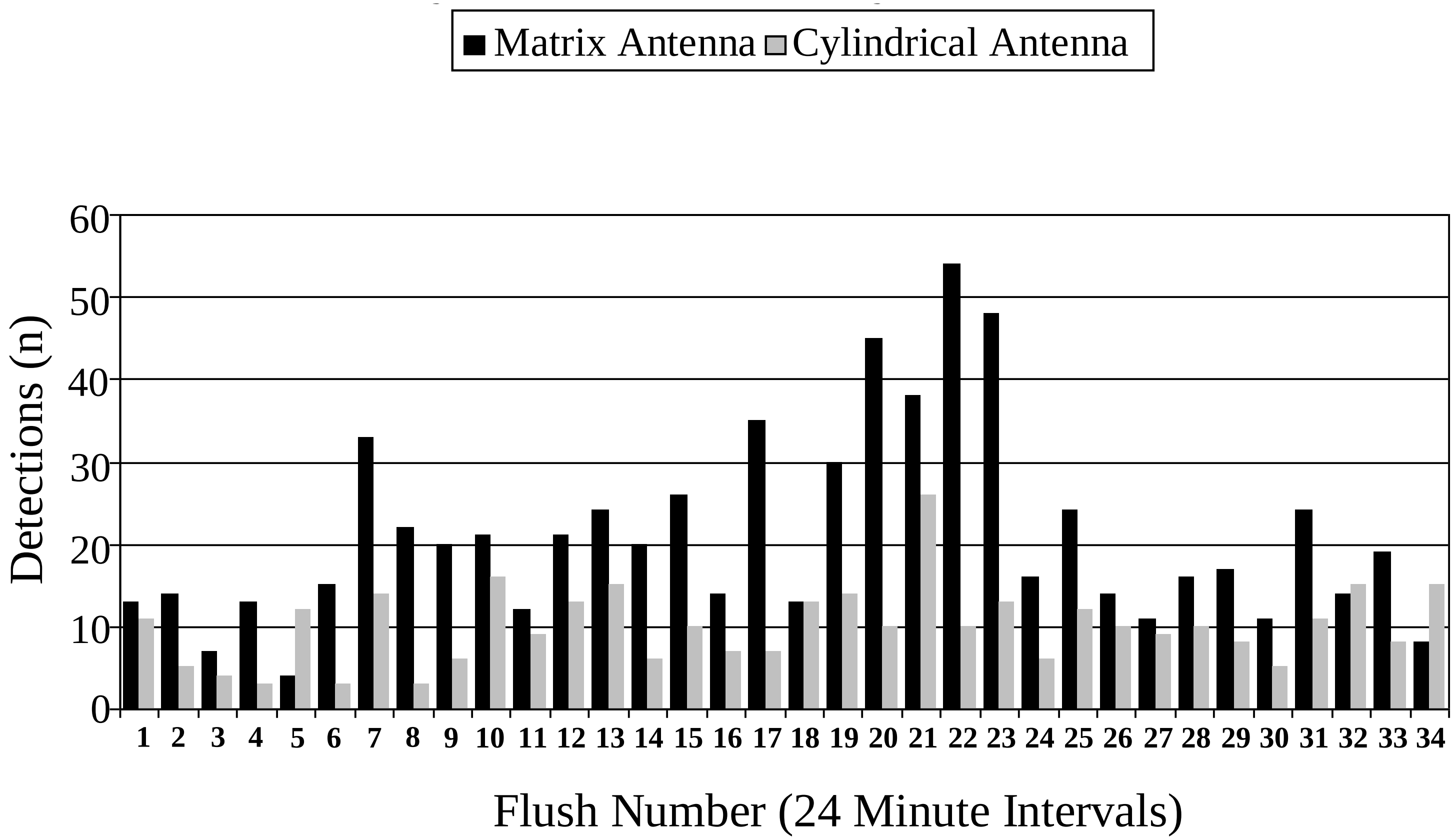



Figure 11. Results of simultaneous sampling with the matrix and cylindrical antenna systems on 13, 14, and 15 May 2009. Results show a 111% increase in overall detections with the matrix system after 14.5 h of sampling. Net flushes (occurring every 19 min and lasting for 5 min) were conducted simultaneously and required both wings of the trawl to be drawn together to a position parallel to the outside of the trawl body.

Table 5. Detections of Chinook salmon and steelhead during the net open and net flush periods using the cylindrical and matrix PIT-tag sampling systems within the two-shift sampling effort (30 April to 14 June) in 2008

| | Chinook | | Steelhead | | |
|---|---|---|---|---|---|
| | n | (%) | n | (%) | Overall % |
| Cylindrical antenna | | | | | |
| Open net | 84 | 18.8 | 110 | 28.5 | 23.3 |
| Net flush | 362 | 81.2 | 276 | 71.5 | 76.7 |
| Matrix antenna | | | | | |
| Open net | 1808 | 29.0 | 1175 | 35.6 | 31.3 |
| Net flush | 4436 | 71.0 | 2123 | 64.4 | 68.7 |

**Impacts on Fish**

During inspection or retrieval of the trawls, we counted juvenile salmonids that were observed to be impinged, injured, or dead on the nets. We recorded 22 of these impinged fish during sampling with the cylindrical detection system, and another 178 during sampling with the matrix system (Appendix Table 4). It is possible that additional dead or impinged fish were lost during the net inversion process used with the cylindrical system. In past years, divers inspecting the trawl body and wing areas have reported that fish rarely swam close to the webbing, but that fish tended to linger near the entrance to the trawl body and fish passage opening. Because of its larger fish passage opening, the matrix antenna system generally passes more debris than the cylindrical system. This would reduce the impact of accumulated debris on fish moving through the system.

In previous years, divers also identified fish pacing in areas of visible transition in the trawl, such as the seams between mesh sizes and near the antennas. Fish delay in these areas can result in fatigue. To discourage pacing, we replaced net sections to produce a uniform color of webbing (black) in the trawl body and cod-end, which expedited fish passage. Although volitional passage through the antennas occurred while towing with the wings extended, we continued to flush the net every 19 minutes to ensure passage. Most fish were detected during these 5-min net-flushing periods.

## Diel Detection Patterns

Between 30 April and 14 June 2008, we conducted two daily sampling shifts and detected a total of 8,155 yearling Chinook salmon and 5,686 steelhead. We calculated the hourly diel detection distributions for each species and compared these distributions to average distributions obtained during the same intensive sample periods (two shifts per day) from 2003 through 2007 (Figure 12). Detections of juvenile sockeye and coho salmon were too few for meaningful comparison. During the two-shift sample period in 2008, the trawl systems were deployed for an average of 12 h $d^{-1}$. Sampling was interrupted between 1400 and 1900 PDT for crew changes and fueling of vessels (Appendix Table 5).

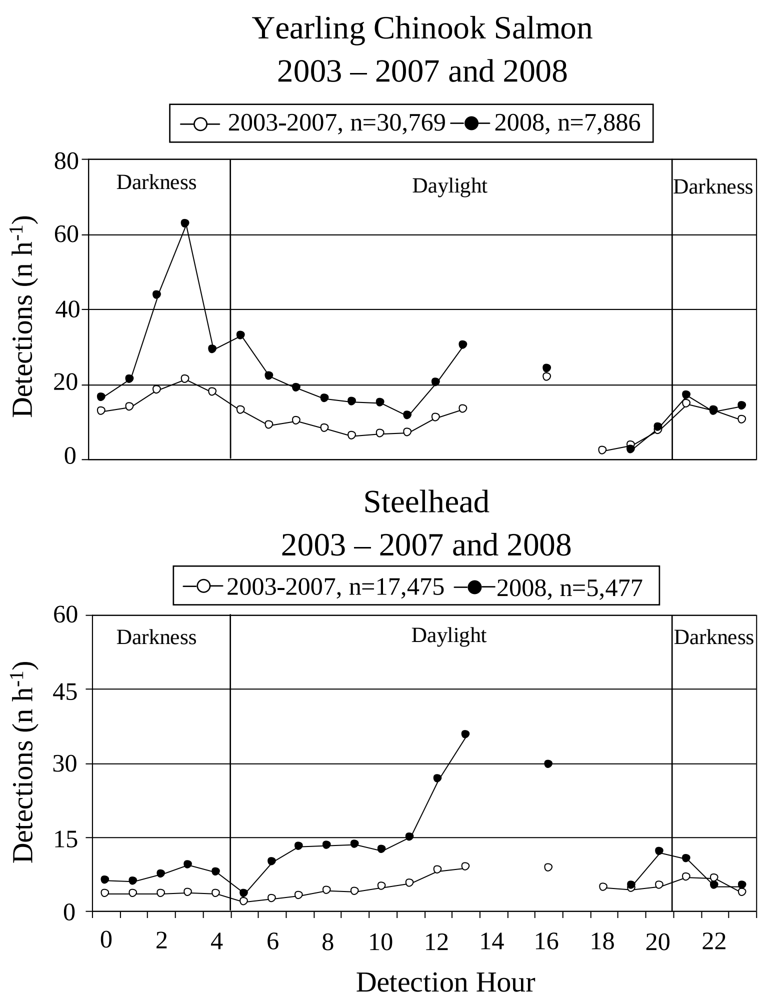



Figure 12. Average hourly detection rates for yearling Chinook salmon and steelhead during two-shift sampling periods in 2003-2007 vs. 2008. In all years, sampling was conducted with the large trawl in the upper estuary (rkm 75).

Hourly detection rates were significantly greater during nighttime (2100-0500) for both hatchery (25 vs. 12 fish $h^{-1}$, $P = 0.03$) and wild yearling Chinook salmon (3 vs. 2 fish $h^{-1}$, $P = 0.05$). However, hourly detections rates did not differ significantly between darkness and daylight hours for either hatchery (5 vs. 12 fish $h^{-1}$, $P = 0.11$) or wild steelhead (2 vs. 4 fish $h^{-1}$, $P = 0.19$). No significant differences have been observed in hourly detection distributions between rearing types since 2003; thus, we pooled hatchery and wild totals for presentation in Figure 12. Typically, Chinook salmon have been more numerous during darkness hours, often significantly, and steelhead more numerous during daylight hours, though rarely significantly.

## Timing and Migration History

### Yearling Chinook Salmon and Steelhead

Median travel times from the tailrace of Lower Granite Dam (rkm 695) to detection in the estuary trawl are shown in Table 6. Respective median travel time was slower in 2008 than in 2007 for yearling Chinook salmon (18.3 vs. 15.7 d), but faster for steelhead (14.4 vs. 15.6 d). Overall, travel time for yearling Chinook salmon and steelhead from Lower Granite Dam in 2008 was similar to previous years since 2000. The exception was 2001, a low-flow year when median travel time was greater than 30 d for both species.

Median travel time to the estuary for yearling Chinook salmon detected at Bonneville Dam in 2008 was the same as in 2007 (1.7 d), whereas for steelhead detected at Bonneville Dam, travel times were slightly faster in 2008 than in 2007 (1.6 vs. 1.7 d, respectively). For fish released from barges just downstream from Bonneville Dam, median travel times to the estuary were faster in 2008 than in 2007, respectively, for yearling Chinook (2.1 d vs. 2.2 d) and steelhead (1.6 vs. 1.7 d).

We also compared the daily differences in travel speeds of fish to the estuary based on migration history (transported vs. inriver) and river flow (Figure 13). Travel speed to the estuary was significantly slower for yearling Chinook salmon released from barges (median 70 km $d^{-1}$) than for those detected at Bonneville Dam during the same period (median 93 km $d^{-1}$; $P = 0.000$). The difference was similar to observations from previous study years. Steelhead traveled significantly faster to the estuary following detection at Bonneville Dam than did steelhead released from barges (medians 97 and 94 km $d^{-1}$, respectively; $P = 0.000$) during the same period. Interactions between date of release from a barge or detection at Bonneville Dam, flow, and migration history were found in some comparisons.

Table 6. Median travel time to the estuary for yearling Chinook salmon and steelhead detected or released at Lower Granite Dam. Fish migrated in the river and were detected at Bonneville Dam, or were transported and released downstream from Bonneville Dam. Mean flow volume at Bonneville Dam from mid-April through the end of June is shown for 2000-2008.

| Year | Flow ($m^3 s^{-1}$) | Yearling Chinook salmon | | Steelhead | |
|---|---|---|---|---|---|
| | | Travel time (d) | Sample (n) | Travel time (d) | Sample (n) |
| | | Time from detection or release at Lower Granite Dam (rkm 695) | | | |
| 2000 | 7,415 | 17.4 | 681 | 17.1 | 833 |
| 2001 | 3,877 | 32.9 | 680 | 30.1 | 44 |
| 2002 | 8,071 | 18.2 | 538 | 17.8 | 93 |
| 2003 | 7,120 | 17 | 563 | 16.5 | 95 |
| 2004 | 6,663 | 16.6 | 867 | 16.6 | 153 |
| 2005 | 5,776 | 17.3 | 1,183 | 16.9 | 278 |
| 2006 | 9,435 | 14.7 | 628 | 12.5 | 110 |
| 2007 | 6,858 | 15.7 | 1,196 | 15.6 | 117 |
| 2008 | 8,714 | 18.3 | 568 | 14.4 | 392 |
| | | Time from detection at Bonneville Dam (rkm 234) | | | |
| 2000 | 7,415 | 1.7 | 479 | 1.7 | 296 |
| 2001 | 3,877 | 2.3 | 792 | 2.5 | 59 |
| 2002 | 8,071 | 1.8 | 1,137 | 1.7 | 156 |
| 2003 | 7,120 | 1.8 | 1,721 | 1.7 | 567 |
| 2004 | 6,663 | 1.9 | 672 | 2 | 110 |
| 2005 | 5,776 | 1.8 | 81 | 2 | 471 |
| 2006 | 9,435 | 1.7 | 888 | 1.6 | 131 |
| 2007 | 6,858 | 1.7 | 1,510 | 1.7 | 362 |
| 2008 | 8,714 | 1.7 | 749 | 1.6 | 830 |
| | | Time from release from transportation barge (rkm 225) | | | |
| 2000 | 7,415 | 1.9 | 495 | 1.6 | 301 |
| 2001 | 3,877 | 2.9 | 1,329 | 2.3 | 244 |
| 2002 | 8,071 | 2 | 1,958 | 1.6 | 296 |
| 2003 | 7,120 | 2.1 | 2,382 | 1.7 | 435 |
| 2004 | 6,663 | 2.2 | 2,997 | 1.9 | 333 |
| 2005 | 5,776 | 2.2 | 2,910 | 1.9 | 400 |
| 2006 | 9,435 | 2.1 | 1,315 | 1.6 | 170 |
| 2007 | 6,858 | 2.2 | 1,096 | 1.7 | 143 |
| 2008 | 8,714 | 2.1 | 1,884 | 1.6 | 788 |

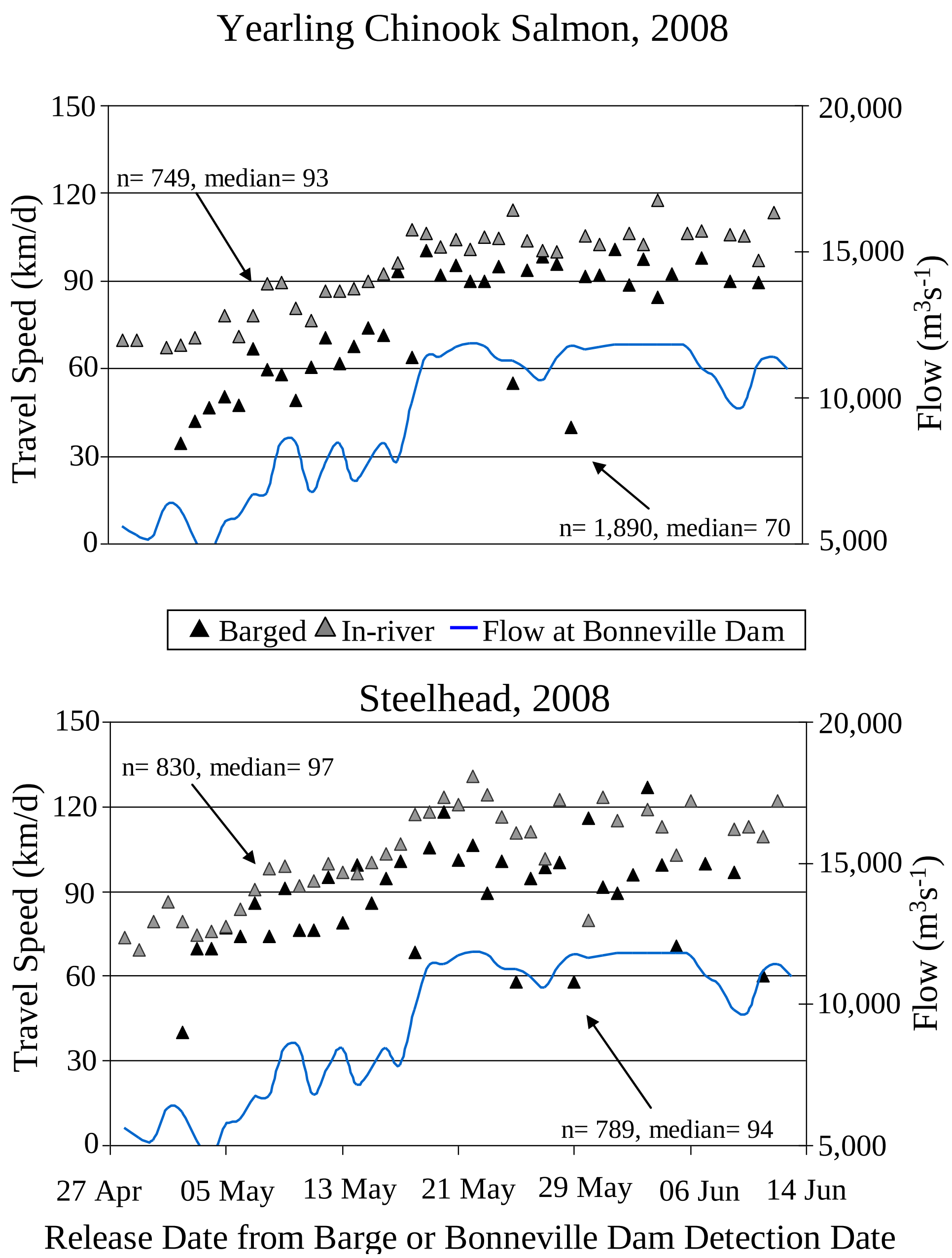



Figure 13. Daily mean travel speed to the estuary of yearling Chinook salmon (top) and steelhead (bottom) following detection at Bonneville Dam or release from a barge to detection in the estuary (rkm 75, cylindrical antenna system), 2008.

### Subyearling Chinook Salmon

We detected 1,697 subyearling Chinook salmon, nearly all of which had been tagged and released after 30 April 2008 and were less than 120 mm fork-length. Most fall Chinook salmon released to migrate prior to 30 April were greater than 120 mm when tagged. Because of their large size at tagging, we could not be sure these fish were subyearlings, and they were not included in analyses of subyearlings. We detected 396 transported and 1,301 inriver migrant subyearling fall Chinook salmon between May and mid-August (Figure 14). Of the subyearling Chinook salmon detected, 77% were released in the Snake River, 12% originated in the Columbia River between Bonneville and McNary Dams, 8% originated in the Columbia River at or upstream from McNary Dam, and 3% originated in the lower Columbia River at or downstream from Bonneville Dam.

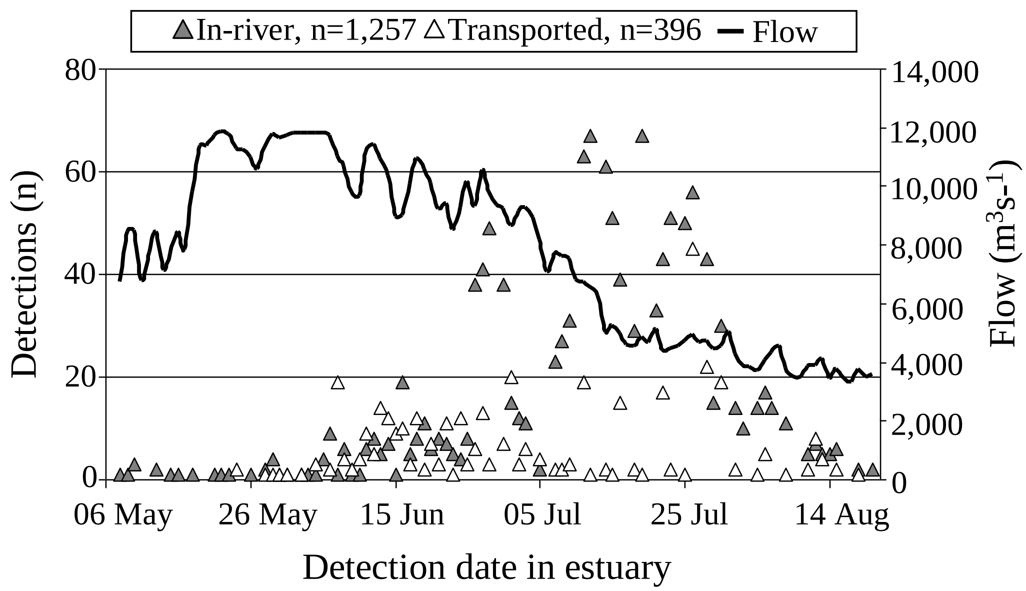



Figure 14. Temporal detection distribution for subyearling Chinook salmon in the estuary following release from barges or for inriver migrants previously detected passing Bonneville Dam; daily river flow volume at Bonneville Dam is shown for comparison, 2008.

For PIT-tagged subyearlings, daily average travel speed decreased with decreasing river flow for both transported fish and inriver migrants (Figure 15). Median travel speed to the estuary for subyearlings in 2008 was 64 km $d^{-1}$ for transported fish and 85 km $d^{-1}$ for inriver migrants. Small sample sizes precluded any meaningful statistical analyses of these results.

Subyearling fall Chinook salmon released in summer 2007 that overwintered in the basin were considered holdovers. In 2008, we detected one Snake River holdover in the upper estuary on 19 May. This fish was double-tagged with both a PIT and acoustic tag on 12 July 2007 at Lower Granite Dam. It was released to the tailrace without any subsequent PIT-tag detections at detection facilities downstream except for the pair-trawl detection system.

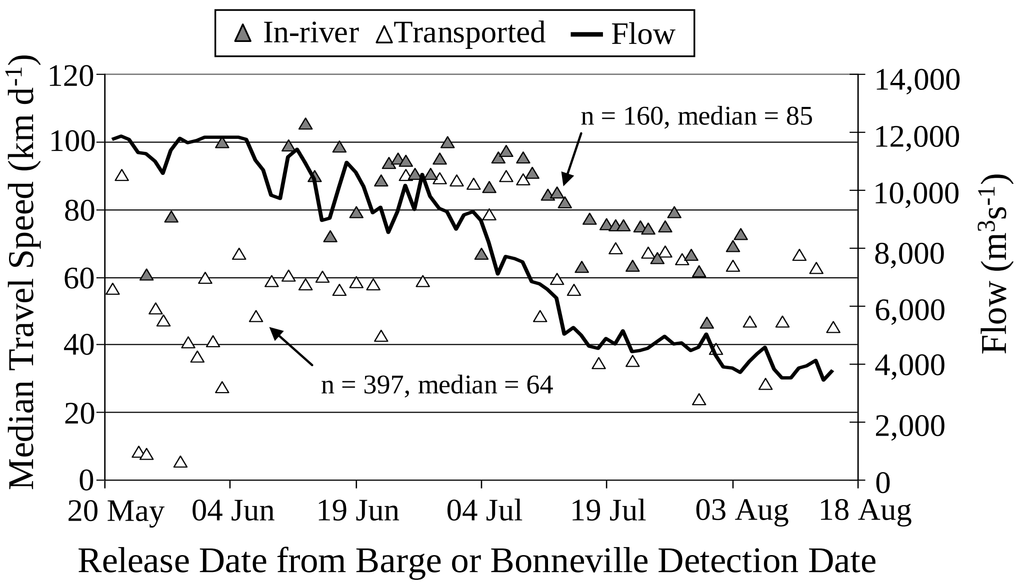



Figure 15. Daily mean travel speed for subyearling Chinook salmon to the estuary following release from barges or for inriver migrants previously detected passing Bonneville Dam; daily river flow volume at Bonneville Dam is shown for comparison, 2008.

## Transportation Evaluation

For the NMFS transportation study in 2008, 49,427 yearling Chinook salmon, 69,718 subyearling Chinook salmon, and 87,601 steelhead were PIT tagged at Lower Granite Dam. A total of 138,826 Chinook salmon and 84,109 steelhead were transported and released upstream from the estuary sampling site during our two-shift sample period, including transportation study fish and fish tagged and transported for other studies. Of these transported fish, we detected 2,363 yearling Chinook salmon and 1,602 steelhead (Appendix Tables 6-7). Of fish released at locations above, McNary Dam to migrate inriver, a total of 31,276 yearling Chinook salmon and 23,345 steelhead were detected passing Bonneville Dam. Of those, we detected 760 yearling Chinook salmon and 837 steelhead (Appendix Table 8).

As in previous years, only a small proportion of transported or inriver migrant groups passed through the estuary before or after the trawl sampling period in 2008. Allowing 2 d to reach the sample area, 81% of transported juvenile salmonids and 60% of those detected at Bonneville Dam were at or near rkm 75 during the two-shift sample period (30 April to 14 June; Table 7). During that period, we detected 1.7% of the transported juvenile Chinook salmon, and 2.4% of those previously detected passing Bonneville Dam. For steelhead, we detected 1.9% of the transported fish and 3.6% of the inriver migrants detected at Bonneville.

Table 7. Pair-trawl detection rates for PIT-tagged fish released from barges or inriver migrants detected passing Bonneville Dam during the daily two-shift sample period from 30 April to 14 June 2008. The release totals during this period represent 94% of the annual totals and were selected allowing 2 d for fish to travel to the sample area.

| | Barged | | | Inriver | | |
|---|---|---|---|---|---|---|
| | Released | Detected | % | Released* | Detected | % |
| Chinook salmon | 138,826 | 2,363 | 1.7 | 31,276 | 760 | 2.4 |
| Steelhead | 84,109 | 1,602 | 1.9 | 23,345 | 831 | 3.6 |

* Fish passing Bonneville Dam and detected in juvenile bypass system or corner collector bypass.

## Detections of Transported vs. Inriver Migrant Fish

Using logistic regression analysis, we compared daily detection percentages of transported fish to those of inriver migrant fish previously detected at Bonneville Dam during the daily two-shift sampling period. Early season transport releases often occurred before there were sufficient inriver migrant fish detected at Bonneville Dam for comparison. For analyses of migration history, we used only inriver migrant fish that had originated at or upstream from the transportation dams. We also used logistic regression to model the daily detection rates of fish released from the same daily transport barges but loaded at different dams.

Regression analysis of detection rates for yearling Chinook salmon showed significant interaction between migration history and date (of barge release or detection at Bonneville Dam; $P = 0.001$; Figure 16, top panel), but no significant interaction between migration history and date-squared ($P = 0.796$). Estimated detection rates for inriver migrant yearling Chinook salmon decreased from around 3% early in the season to 2% by late May and to less than 1.0% by mid-June. Conversely, estimated detection rates for barged yearling Chinook salmon were lower early in the season (1.5-2.0%) and gradually increased to follow a similar pattern as observed for inriver migrants from mid-May through mid-June. The adjustment for overdispersion was 11.4.

Regression analysis of detection numbers for steelhead showed no significant interaction between date or date-squared and migration history ($P = 0.487$ and 0.071, respectfully); however, detection rates were significantly different dependent on migration history ($P \leq 0.001$). Date-squared was not a significant factor in the seasonal trend ($P = 0.861$). Detection rates of both barged and inriver migrant steelhead decreased steadily throughout the two-shift period from 5.5 and 3.0%, to 1.5 and 1.0%, respectively (Figure 16, bottom panel). The adjustment for overdispersion was 12.8. As in 2005-2007, daily detection data for steelhead were more variable than for yearling Chinook salmon.

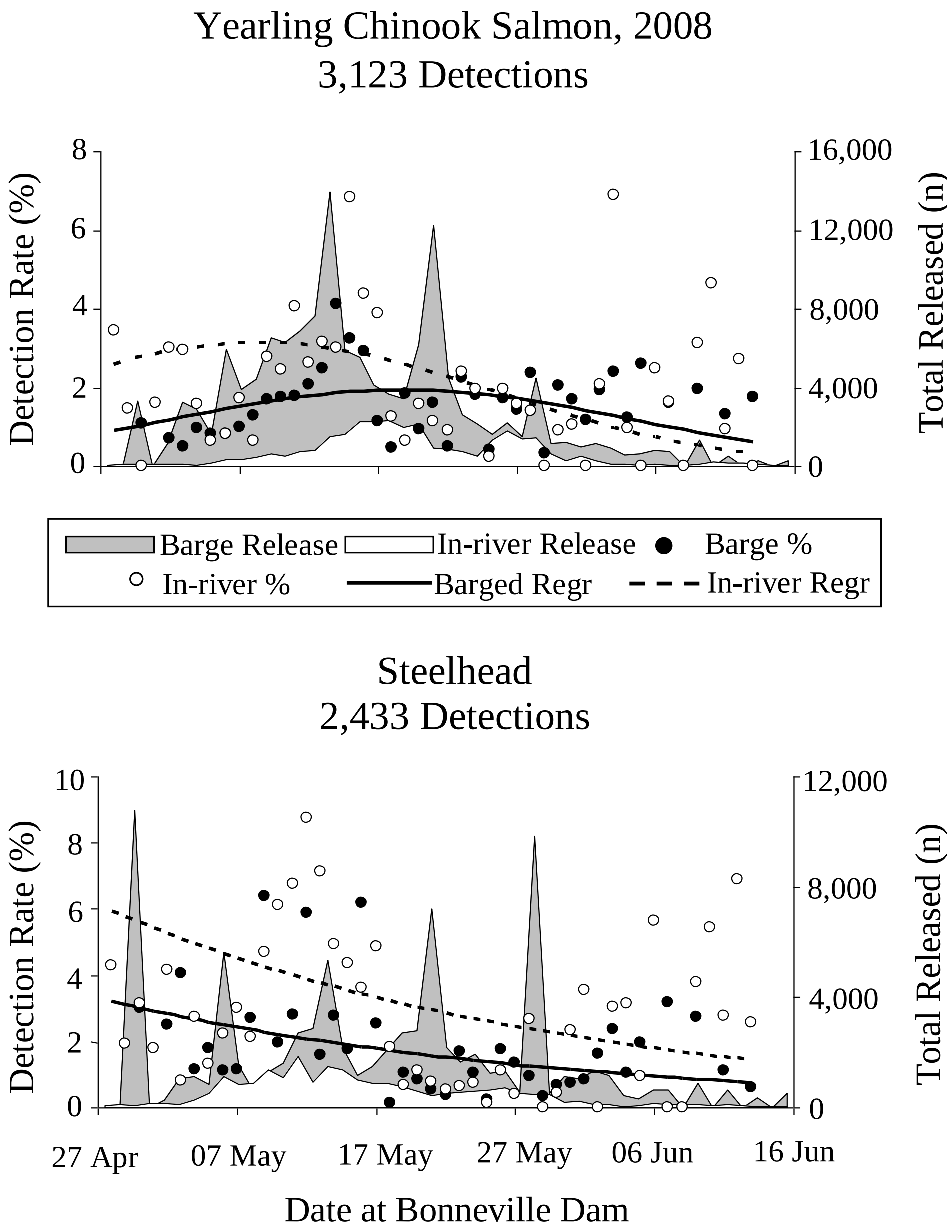



Figure 16. Logistic regression analysis of the daily detection percentage of transported and inriver migrant yearling Chinook salmon and steelhead detected at or released near Bonneville Dam on the same dates, 2008.

## Mixing Assessment:  Transported vs. Inriver Migrants

Comparisons of relative detection rates between transported fish and inriver migrants were based on the assumption that probabilities of detection in the estuary were equal between fish released from barges near Bonneville Dam and those detected in the bypass systems at the dam on the same date.  To test the validity of this assumption, we calculated hourly differences in detection distributions between the two groups during the two-shift sample period for each year since 2000 (Figure 17).

Average hourly detection rates for yearling Chinook salmon varied from 0 to 4%. There did not appear to be strong trends in the hourly differences for either group of yearling Chinook salmon.  This supported the assumption that transported and inriver migrant fish were mixed during passage through the estuary.  The extreme values in most years represented intervals with low sampling effort (shift-change periods) and perhaps low detection numbers for one group or another during the time of year that those interval hours were sampled.  Variability was most extreme for 2001 (range, -9 to 7%), and for 2005 when most in-river fish (-9%) were detected at 14:00 and most barged fish (5%) at 21:00.

For steelhead, average hourly differences in detections for the same period varied from 0 to 3%.  While data from individual years indicated the possibility of a trend, when analyzed together, there did not appear to be strong trends in the differences for either group.  This finding also supported the assumption that transported fish and those detected at Bonneville Dam were mixed during passage through the estuary.  For example, sampling data from 2000 and 2006 suggested that higher percentages of barged steelhead were present during mid-day and less were present in the evenings, while 2001 data suggested the opposite.  Ranges of difference were greatest in 2000, 2001, and 2006, when sample sizes of steelhead were larger.

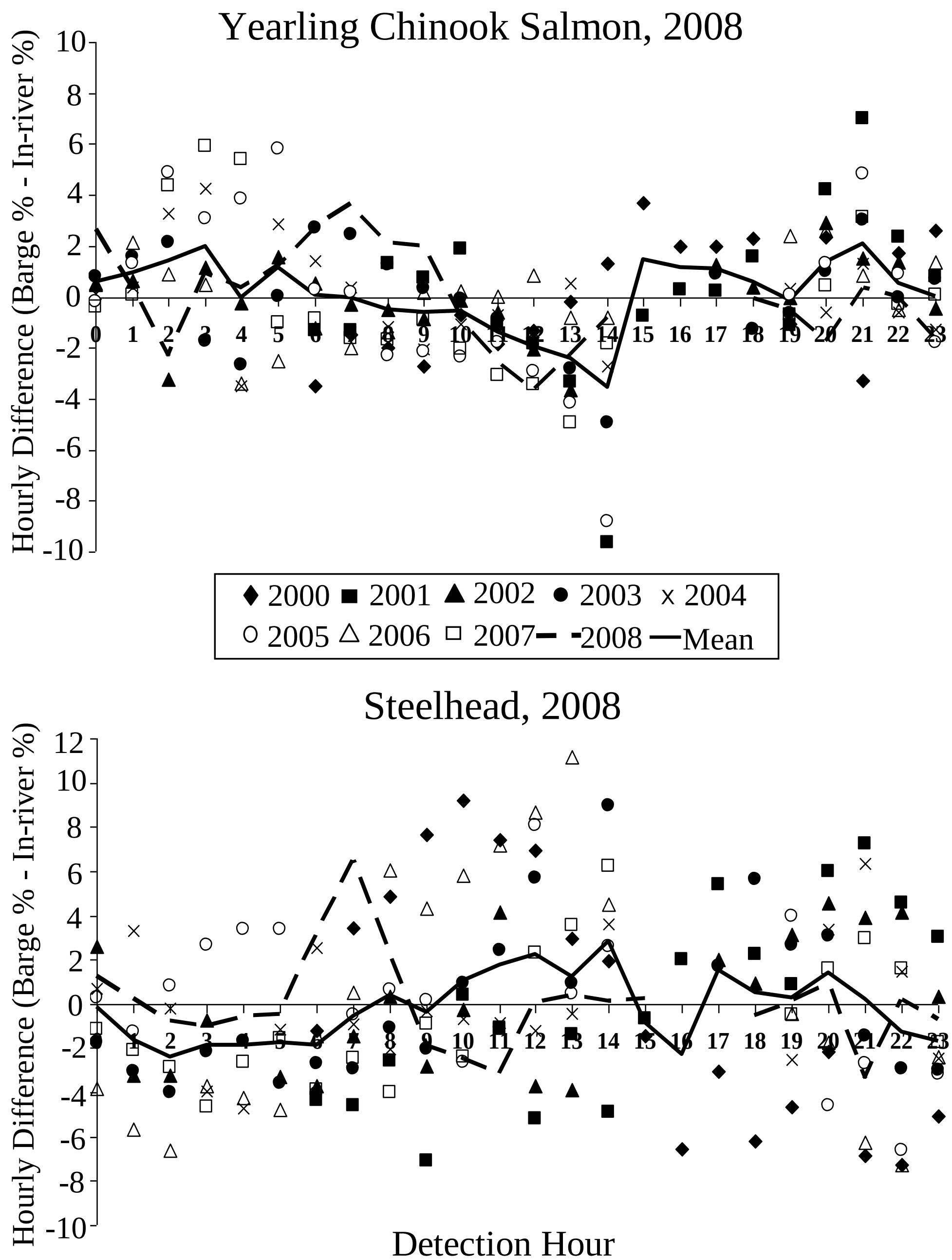



Figure 17. Hourly difference in estuarine detection percentages of barge-released fish compared to those fish previously detected at Bonneville Dam during two-shift sampling periods, 2000-2008. The pooled mean difference is plotted. A mean difference greater than zero indicated that a higher proportion of transported fish were detected, while a mean lower than zero indicated more inriver fish were detected.

## Transport Dam Assessment

There was no significant interaction between Snake River transport dam and barge release date ($P$ = 0.653) or date-squared ($P$ = 0.189) for yearling Chinook salmon (Figure 18, top panel). Detection rates for fish transported from Lower Granite Dam decreased from 2.3% in mid-May to 1.1% in late May and then increased to 1.6% by mid-June. Detection rates for fish from Little Goose and Lower Monumental Dams combined showed a similar, but significantly higher ($P$ < 0.001) detection pattern, where detection rates decreased from 3.5 to 1.6% and then increased to 2.4%. Coefficients for date and date-squared estimated from the model indicated that these patterns were significantly different from a constant value through time ($P$ = 0.009 and 0.001, respectively). The adjustment for overdispersion was 8.0.

There was significant interaction in the estimated estuarine detection rate between Snake River transport dam and barge release date for steelhead ($P$ = 0.032 and $P$ = 0.037 for date and date-squared, respectively; Figure 18, bottom panel). During the two-shift sampling period, and when all dams were in transportation mode, detection rates of steelhead from Lower Granite Dam decreased from over 6.0 to 1.0% by late May and then increased to 3.0% by mid-June. In contrast, for steelhead from Little Goose and Lower Monumental Dams combined, detection rates decreased from 3.0% in mid-May to 1.5% in late May and then increased to 3.0% by mid-June. The adjustment for overdispersion was 7.4.

## Survival Estimates of Inriver Migrants to the Tailrace of Bonneville Dam

Detection data from the trawl are essential for calculating survival probabilities for juvenile salmonids to the tailrace of Bonneville Dam, the last dam encountered by seaward migrants (Muir et al. 2001; Williams et al. 2001; Zabel et al. 2002). Detections of yearling Chinook salmon and steelhead arriving at McNary Dam were pooled weekly, and survival probabilities of fish released in the Snake and Columbia Rivers were estimated from McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dam (Table 8).

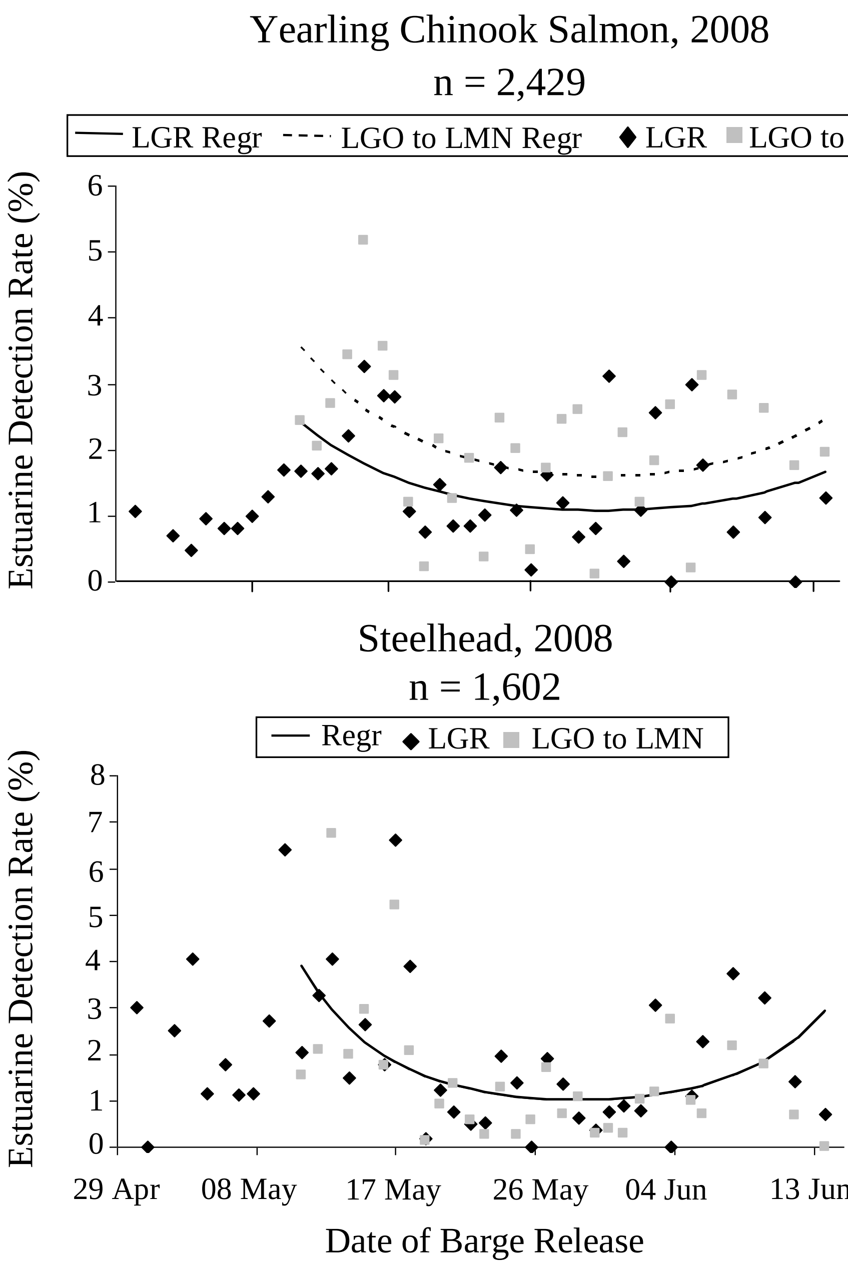



Figure 18. Daily detection rates of yearling Chinook salmon and steelhead released from barges loaded at Lower Granite Dam (LGR) or other downstream dams, Little Goose Dam (LGS) and Lower Monumental Dam (LMN), 2008.

Table 8. Estimated weekly average survival (%) from the tailrace of McNary Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 2008. Blank cells indicate sample sizes were too small for a 1-week estimate; therefore, the week prior is a 2-week pooled estimate.

| | | McNary to John Day Dam | | John Day to Bonneville Dam | | McNary to Bonneville Dam | |
|---|---|---|---|---|---|---|---|
| Date | N | % | SE | % | SE | % | SE |
| | | Snake River yearling Chinook salmon | | | | | |
| 27 Apr-03 May | 588 | 110.3 | 19 | 50.7 | 16.7 | 55.9 | 15.6 |
| 04 Apr-10 May | 7,576 | 98.3 | 5.4 | 76.1 | 8 | 74.8 | 6.7 |
| 11 May-17 May | 24,299 | 119.5 | 6 | 37.9 | 3.6 | 45.3 | 3.6 |
| 18 May-24 May | 13,541 | 117.5 | 9.9 | 68.2 | 18.9 | 80.2 | 21.2 |
| 25 May-31 May | 3,244 | 73.1 | 8.4 | NA | NA | NA | NA |
| 01 Jun-07 Jun | 1,239 | 96.2 | 16.4 | 79.5 | 54.4 | 76.4 | 50.7 |
| 08 Jun-14 Jun | 716 | 74.7 | 20.2 | 64 | 60.6 | 47.8 | 43.4 |
| Wt. Avg. | 51,203 | 107.3 | 5.8 | 55.9 | 8.2 | 59.3 | 6.6 |
| | | Snake River steelhead | | | | | |
| 20 Apr-26 Apr | 329 | 85.7 | 21.7 | 35.6 | 15.8 | 30.5 | 11 |
| 27 Apr-03 May | 1,612 | 94.2 | 10 | 70.6 | 19.8 | 66.5 | 17.3 |
| 04 May-10 May | 4,569 | 86 | 4.1 | 80.2 | 7.7 | 69 | 5.8 |
| 11 May-17 May | 3,729 | 110.1 | 10.4 | 65.4 | 14.2 | 72 | 14 |
| 18 May-24 May | 2,420 | 107 | 12.9 | 69 | 38 | 73.9 | 39.6 |
| 25 May-31 May | 1,280 | 170.4 | 35.1 | 36.7 | 25.5 | 62.5 | 41.5 |
| 01 Jun-07 Jun | 844 | 90.6 | 13.8 | 49.2 | 22.6 | 44.6 | 19.4 |
| Wt. Avg. | 14,783 | 94.9 | 6.6 | 74.3 | 4.5 | 67.1 | 3.4 |
| | | Mid-Columbia River yearling Chinook | | | | | |
| 04 May-10 May | 431 | 109 | 17.5 | 39.3 | 16.8 | 42.8 | 17 |
| 11 May-17 May | 1,296 | * | * | * | * | * | * |
| 18 May-24 May | 1,392 | 96.9 | 14.4 | NA | NA | NA | NA |
| 25 May-31 May | 944 | * | * | * | * | * | * |
| 01 Jun-07 Jun | 277 | 93.7 | 30.5 | 47.3 | 45.1 | 44.4 | 39.6 |
| 08 Jun-14 Jun | 221 | * | * | * | * | * | * |
| 15 Jun-21 Jun | 153 | 46.9 | 18.6 | NA | NA | NA | NA |
| 22 Jun-28 Jun | 76 | * | * | * | * | * | * |
| Wt. Avg. | 4,790 | 98.1 | 8.5 | 40.6 | 3 | 43.1 | 0.6 |
| | | Mid-Columbia River steelhead | | | | | |
| 04 May-10 May | 53 | 102.2 | 23.5 | NA | NA | NA | NA |
| 11 May-17 May | 690 | * | * | * | * | * | * |
| 18 May-24 May | 963 | 108.3 | 16.9 | NA | NA | NA | NA |
| 25 May-31 May | 803 | * | * | * | * | * | * |
| 01 Jun-07 Jun | 332 | 78.3 | 17.6 | NA | NA | NA | NA |
| 08 Jun-14 Jun | 191 | * | * | * | * | * | * |
| 15 Jun-21 Jun | 70 | 96.8 | 58.2 | NA | NA | NA | NA |
| 22 Jun-28 Jun | 23 | * | * | * | * | * | * |
| Wt. Avg. | 3,125 | 99.3 | 7 | NA | NA | NA | NA |

* Mid-Columbia River Chinook and steelhead survival estimates are two-week averages.

Weighted annual survival estimates from 1999 to 2008 were compared for both Snake and Columbia River basin stocks (Figure 19). For some species in some years, there were insufficient numbers of tagged fish released to compare between watersheds. However, there did not appear to be a general trend in survival between the two sources for either species. For Snake River yearling Chinook salmon, annual survival estimates from the tailrace of McNary Dam to the tailrace of Bonneville Dam ranged from 50.1% in 2001 to 84.2% in 2006. For Columbia River yearling Chinook estimates ranged from 57.0% in 1999 to 76.7% in 2003. Survival estimates for steelhead ranged from 25.0% in 2001 to 77.0% in 1998 (67.1% in 2008) for Snake River stocks and 39.2% in 2007 to 74.2% in 1999 for Columbia River stocks (estimate not available for 2008). In addition, during the drought year of 2001, there were insufficient fish tagged in the mid-Columbia to compare with record low survivals recorded for the Snake River stocks.

Fish transported from Lower Granite, Little Goose, or Lower Monumental Dams on the Snake River or at McNary Dam on the Columbia River pass three to seven downstream dams. The effectiveness of transportation is evaluated in part by comparing smolt to adult return (SAR) ratios between transported fish and inriver migrants. The annual benefit of transportation is partly dependent upon river conditions experienced by fish left to migrate through the hydropower system. In 2007, seasonal average survival of inriver migrant yearling Chinook salmon and steelhead from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 59.7 and 36.4%, respectively. In 2008, the survival estimates were slightly lower for yearling Chinook salmon (41.9) and higher for steelhead (45.8%; Table 9).

We speculate that higher survival years for inriver migrants are associated with increased flow volumes. In 2001 and 2004, two years characterized by extremely low river flows, survival probabilities for yearling Chinook salmon were much lower than in other years (27.9 and 39.5%, respectively). In 2008, flow volumes were generally lower-than-average prior to mid-May and higher-than-average from mid-May to mid-June. Similarly, survival probabilities for Snake River steelhead through the entire hydropower system downstream from Lower Granite Dam in 2008 (45.8%) were higher than in any year since 1998 (50.0%). Again, though exceptionally low survival was estimated in 2001 for inriver migrant steelhead (4%), this was a drought year during which most fish were transported.

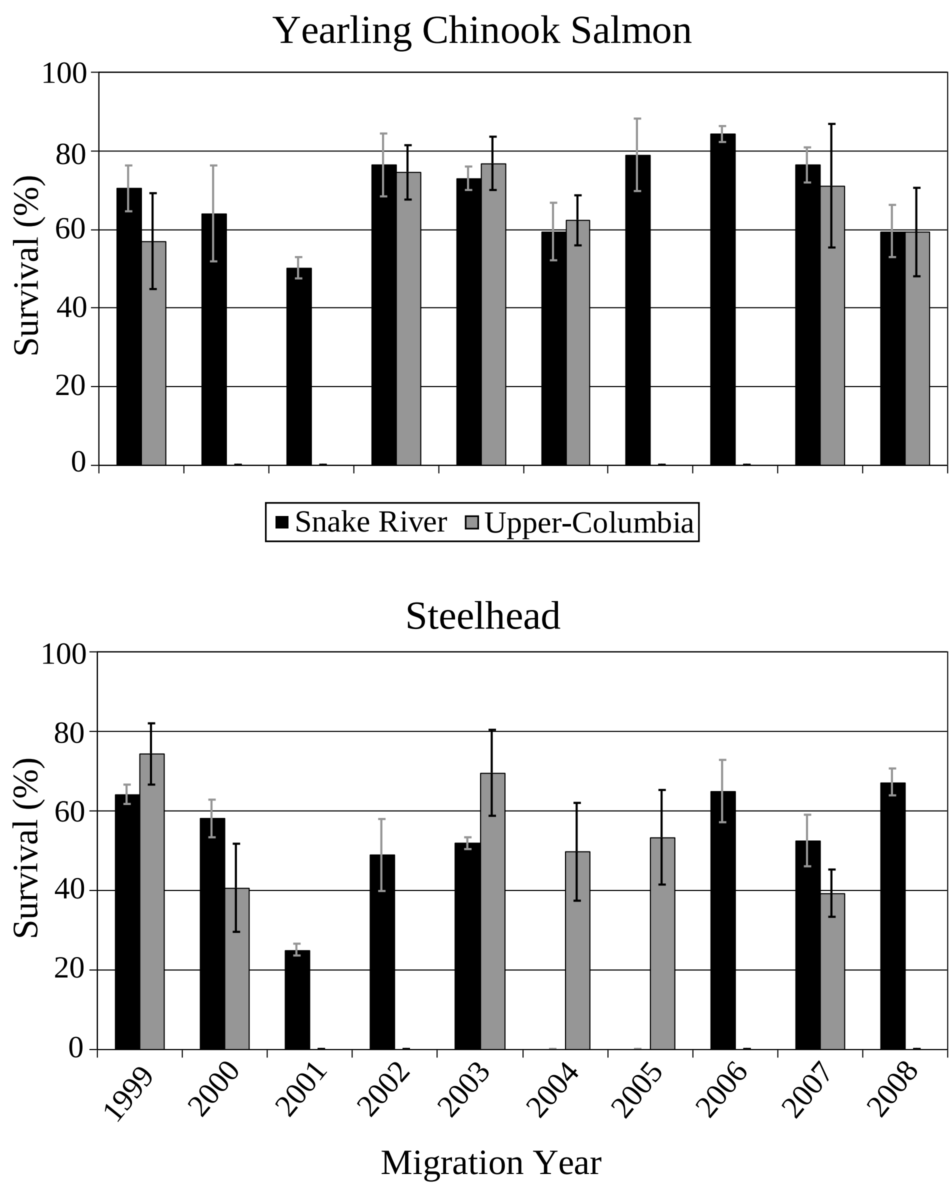



Figure 19. Weighted average annual survival and SE from the tailrace of McNary Dam to the tailrace of Bonneville Dam, for Snake and Columbia River yearling Chinook salmon and steelhead, 1999-2008.

Table 9. Estimated probabilities with standard errors for survival from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam for yearling Chinook salmon and steelhead, 1998-2008.

| | Survival estimates | | | |
|---|---|---|---|---|
| | Yearling Chinook salmon | | Steelhead | |
| Migration year | (%) | SE | (%) | SE |
| 1998 | 53.8 | 4.6 | 50 | 5.4 |
| 1999 | 55.7 | 4.6 | 44 | 1.8 |
| 2000 | 48.6 | 9.3 | 39.3 | 3.4 |
| 2001 | 27.9 | 1.6 | 4.2 | 0.3 |
| 2002 | 57.8 | 6 | 26.2 | 5 |
| 2003 | 53.2 | 2.3 | 30.9 | 1.1 |
| 2004 | 39.5 | 5 | * | * |
| 2005 | 57.7 | 6.9 | * | * |
| 2006 | 64.3 | 1.7 | 45.5 | 5.6 |
| 2007 | 59.7 | 3.5 | 36.4 | 4.5 |
| 2008 | 46.5 | 5.2 | 48.0 | 2.6 |

* Sample size too small to estimate annual survival probability

## DISCUSSION

Detections from the trawl systems in the estuary provide data for many research programs (Faulkner et al. 2008, 2009, 2010). For the past several years, researchers and others have released an excess of two million PIT-tagged fish annually into Columbia River basin. Documented passage of these fish through the estuary has increased our understanding of migration behavior and relative survival during the critical freshwater-to-saltwater transition period. Data collected from the trawl were used to evaluate migration timing and survival of PIT-tagged juvenile salmonids released in the Columbia River basin to the upper estuary in 2008. These data allowed us to examine multi-year trends in survival for inriver migrants to the tailrace of Bonneville Dam and relative daily detection rates for fish traveling between Bonneville Dam and the estuary for both inriver migrants and transported fish.

Data collected in the estuary also provided context for smolt-to-adult return ratios (SAR), which have shown substantial temporal variation related to the timing of juvenile migrations. These data can aid in partitioning freshwater effects from ocean effects when evaluating the causes of mortality. For example, large colonies of predacious birds on East Sand Island in the lower estuary have a significant annual impact on juvenile salmonids (Collis et al. 2001; Ryan et al. 2001, 2003; Sebring et al. 2009). Temporal comparisons can now be made between estuary detection rates of fish groups released from transport barges and their inriver migrating cohorts detected in the bypass system at Bonneville Dam. Similar comparisons are possible using PIT-tag data collected from abandoned bird colonies. Both sets of data contribute to better understanding of temporal variation in SARs and the benefits of management actions taken to improve SARs.

We also continued our efforts to adapt the trawl detection systems to new technology, with the goal of improving detection efficiency while minimizing possible impacts to fish. Sampling for PIT tags with trawls in 2008 utilized both the two-coil (0.9-m diameter) cylindrical antenna and six-coil (2.6 × 3.0 m) matrix antenna. We began the season using the cylindrical antenna system and after construction of the matrix antenna was completed in May, we deployed both systems simultaneously during a period when high densities of PIT-tagged fish were present in the estuary.

During simultaneous sampling, we measured the relative detection efficiencies of both systems to evaluate possible negative effects of tag collisions in the larger matrix electronic field. After 3 d of simultaneous deployment, with systems sampling within 1 km of each other, the matrix system detected 53% more PIT-tagged fish than the cylindrical system. The much larger fish passage opening (about 12 times larger) reduced fish avoidance (swimming forward and out of the trawl, possibly without detection) and increased fish passage by about 8.0% during the open period versus the flush period of our sampling cadence. Additionally, environmental noise observed with the two-coil matrix system used in 2007 was not observed in 2008. Based on results of these simultaneous deployments, we utilized the matrix system exclusively for the remainder of the sampling season.

Shortly after simultaneous deployments (on 18 May), a period of extremely high river flow volume and debris loads occurred. These high debris loads forced the removal of fish guidance screens from turbine units at Bonneville Dam and compelled us to cancel some estuary sampling efforts with trawls. If we had not previously switched to the larger matrix antenna and the smaller (0.9-m diameter) antenna was utilized, additional sampling effort would have been lost, possibly compromising the study objectives. The high flows also pushed our trawls through the sampling reach faster than in previous years, and forced us to deploy further upstream to minimize time lost with costly net-retrievals and redeployments, but also reduced sampling time due to the increase in required upstream transit time for deployment.

For example, in 2007, sampling during the two-shift period averaged about 13 h/d compared to a two-shift average of about 12 h/d in 2008. Although these daily sampling averages were similar, the total annual detections were about 14% lower in 2008. The lower annual detection total in 2008 was attributable in part to greater dispersion and faster travel speed of sample fish during the high flow event and to the loss of sampling during a period of high PIT-tagged fish density in the estuary.

PIT-tagged fish passing Bonneville Dam can be detected only at the Second Powerhouse in the corner collector (not entering a turbine intake) or after entering a turbine intake followed by diversion into the bypass system where they are detected at the fish facility. The removal of fish diversion screens from mid-May to early June, due to debris accumulation, significantly reduced fish detections in the juvenile fish facility. At Bonneville Dam, detection numbers for yearling Chinook salmon are generally higher in the juvenile facility, while detections of steelhead are higher in the corner collector. In 2008, decreased numbers of fish were detected at Bonneville Dam, particularly yearling Chinook salmon. This reduced the number of fish available for subsequent detection in the estuary, which weakened estimates of survival to Bonneville Dam during this period.

In 2008, our two-shift sampling coincided with the estimated presence of 60% of all inriver migrating PIT-tagged fish and 81% of all barge transported PIT-tagged fish (compared to 89 and 98%, respectively, in 2007). The lower proportion of available PIT-tagged fish during the two-shift period in 2008 was due to the increased tagging and transportation of subyearling fall Chinook salmon from the Snake River. These fish typically migrate later in the summer and fall, when densities of PIT-tagged fish in the estuary are reduced to levels that no longer warrant the expense of a two-shift daily crew.

Travel speed from the area of Bonneville Dam to the estuary for most fish groups was faster in 2008 than in 2007 and can be directly attributed to the increased river flow volume in the estuary, particularly after 18 May. Overall flows in 2008 averaged 8,714$m^3 s^{-1}$ during the two-shift sample period compared to 6,858$m^3 s^{-1}$ during the same period in 2007 (a 21% increase in flow volume). While travel speed of fish, both daily and seasonally, is strongly correlated with river flow volume, the relative daily travel speeds to the estuary in 2008 were significantly slower for yearling Chinook salmon following release from barges near Bonneville Dam (median 70 km $d^{-1}$) than for those detected at Bonneville Dam on the same date (median 93 km $d^{-1}$). These differences were similar to differences in previous years. To a lesser degree, steelhead released from barges also traveled more slowly to the estuary than did those detected passing Bonneville Dam on the same date (medians 94 and 97 km $d^{-1}$, respectively).

The single-release method of estimating survival to the tailrace of Bonneville Dam is dependent on subsequent detections of fish in the estuary that were previously detected at Bonneville Dam. During 2004 and 2005, proportions of PIT-tagged fish detected at Bonneville Dam declined sharply over previous years, and this decline was associated with successful operation of the new corner-collector bypass system. The corner-collector did not have PIT-tag monitors installed during these initial 2 years of operation.

Installation of PIT-tag monitors in the corner collector was complete in time for the spring migration period of 2006. Since installation, detections in the corner collector have provided data to supplement detections in the juvenile bypass facilities. Detections in these two passage routes considerably increased the number of PIT-tagged fish detected at Bonneville Dam, thereby contributing to improved precision in the survival estimates to the tailrace of Bonneville.

For yearling Chinook salmon migrating through the entire Federal Columbia River Power System (FCRPS), higher survival probabilities were estimated in 2007 than in 2008 (59.7 and 46.5%, respectively). We attribute part of this difference to the removal of fish diversion screens at Bonneville Dam during the height of the spring migration in 2008. Yearling Chinook tend to prefer the juvenile fish facility (JFF) over the corner collector as a route of passage, and the debris load on diversion screens leading to the JFF may have affected survival of fish passing via that route. In comparison, survival probabilities in 2001 and 2004 were much lower (27.9 and 39.5%, respectively) than in 2007 and 2008. The years 2001 and 2004 were characterized by extremely low river flows due to regional drought.

Survival probability for steelhead through FCRPS was higher in 2008 than in all other years except for 1998 (48.0 and 50%, respectively). We speculate that higher steelhead survival probability in 2008 relative to Chinook salmon was related to passage through the corner collector (little debris accumulation). Higher flows and turbidity during 2008 likely reduced travel time and vulnerability to predation for steelhead.

Similar to previous years, detection numbers in 2008 were generally higher during darkness for Chinook salmon and higher during daylight for steelhead. Purse-seine sampling in this river reach also resulted in peak catches of steelhead between 1400 and 1600 (Ledgerwood et al. 1991). The scheduled afternoon shut-downs of trawl sampling for fueling, crew-changes, and maintenance no doubt reduced overall detection numbers for steelhead. However, sampling effort would have been impaired during this daily period in any case, due to the frequency of difficult wind conditions.

Since 2000, our annual sample results have indicated no strong diel trends in detection rates between transported fish and inriver migrants detected at Bonneville Dam. Therefore, for analyses, we assumed that when transported and inriver migrant groups were released/detected on a given day, both were present in the estuary with similar distributions and subjected to the same sampling procedures and river conditions. This assumption was also used in analyses comparing fish released from the same barge but loaded at different dams. Therefore, comparison of daily estuary detection rates between transported fish and inriver migrants detected passing Bonneville Dam on the same date are likely to indicate real differences in survival to the estuary.

During the sampling period in 2008, the detection rates of yearling Chinook salmon in the estuary showed no significant difference between transported fish and inriver migrants, although there was a significant difference in overall detection rates over the entire migration season. For both groups, estimated sampling efficiency was lower early in the two-shift sample period, increased until early May, and then dropped as flows and debris loads increased. Higher flows decreased our detection rates as sampling effort dropped from mid-May to mid-June when two-shift sampling ended.

Estuary detection rates of both barged and inriver migrant steelhead decreased steadily throughout the sample period, reflecting the impact of high flows. However, inriver migrant steelhead arriving at Bonneville Dam were detected at a significantly higher rate in the estuary than those that had been barged. We suspect that much variability in daily detection rates for transported fish may have related to the specifics of barge loading such as species composition, loading densities, and loading sites.

Comparisons of daily detection rates in the estuary for yearling Chinook salmon loaded at various dams and released from the same barge showed no seasonal differences among dams. Detection rates for fish loaded and transported from Lower Granite Dam were about 1% lower than those of fish transported from other dams. There was a significant difference in temporal trends between detections of steelhead loaded at Lower Granite Dam and those loaded at downstream dams. Detection rates of steelhead from Lower Granite Dam decreased from over 6% in late April to 1% by late-May and then increased to 3.0% by mid-June. Detection rates for steelhead loaded at Little Goose and Lower Monumental Dams combined decreased from 3.0% in mid-May to 1.5% in late May and then increased to 3.0% by mid-June. High river flows were the major cause of this variable detection rate during the 2008 spring migration season.

Sampling in fall 2008 was conducted to evaluate the presence of holdover subyearling fall Chinook salmon from the Snake River basin (fish released as subyearlings that delayed migration until the year following release). We operated both the mid-river matrix trawl (35 h) and shoreline trawl system (24 h) from 29 September to 30 October. Only three fish were detected, with only one detected by the shoreline sampler. This fish had been recently transported from the Snake River. The other two fish, which were detected in the mid-river trawl, had originated in the Willamette River.

Previous sampling at Jones Beach indicated that juvenile salmonids orient to the shoreline environment when water temperatures drop during winter and early spring (Dawley et al. 1986). Although these numbers were far too few for meaningful analyses in 2008, the release of large numbers of PIT-tagged subyearling fall Chinook salmon in that year justifies continued sampling for these fish in early spring of 2009 to detect individuals that had overwintered in freshwater.

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## APPENDIX

### Data Tables

Appendix Table 1. PIT-tag layout on a vinyl-tape used to test antenna performance in 2008.

| Position on tape measure (ft) | Orientation (°) | Distance from previous tag (f)[a] | PIT-tag code[b] |
|---|---|---|---|
| 17 | 0 | 0 | 3D9.1BF22F5437 |
| 19 | 0 | 2 | 3D9.1BF1A73554 |
| 21 | 0 | 2 | 3D9.1BF1A723D6 |
| 23 | 45 | 2 | 3D9.1BF1A6BBD5 |
| 25 | 45 | 2 | 3D9.1BF1F8B9A4 |
| 28 | 0 | 3 | 3D9.1BF1A6BE89 |
| 31 | 0 | 3 | 3D9.1BF1F7DDEA |
| 34 | 0 | 3 | 3D9.1BF1A1E4AF |
| 37 | 45 | 3 | 3D9.1BF1CF5597 |
| 40 | 45 | 3 | 3D9.1BF1E73089 |
| 43 | 45 | 3 | 3D9.1BF1F81373 |
| 45 | 0 | 2 | 3D9.1BF1F7D25F |
| 47 | 0 | 2 | 3D9.1BF1F7DC5C |
| 49 | 0 | 2 | 3D9.1BF1F7D8EA |
| 50 | 0 | 1 | 3D9.1BF1A71E13 |
| 51 | 0 | 1 | 3D9.1BF1A1CD75 |
| 52 | 0 | 1 | 3D9.1BF1F7CDF7 |
| 55 | 0 | 3 | 3D9.1BF1F8F242 |
| 58 | 0 | 3 | 3D9.1BF1A7A629 |
| 59 | 0 | 1 | 3D9.1BF1F85701 |
| 62 | 0 | 3 | 3D9.1BF1A72BFD |
| 63 | 0 | 1 | 3D9.1BF1F8CAB0 |
| 66 | 0 | 3 | 3D9.1BF1F8BBEB |
| 69 | 45 | 3 | 3D9.1BF1F7CD88 |
| 70 | 45 | 1 | 3D9.1BF1A9ADDC |
| 72 | 0 | 2 | 3D9.1BF1F7268D |
| 73 | 0 | 1 | 3D9.1BF1A972D5 |
| 75 | 0 | 2 | 3D9.1BF1A6B38B |
| 77 | 0 | 2 | 3D9.1BF1F81389 |

Appendix Table 1  Continued.

| Position on tape measure (ft) | Orientation (°) | Distance from previous tag (f)[a] | PIT-tag code[b] |
|---|---|---|---|
| 81 | 0 | 4 | 3D9.1BF1A98D9E |
| 83 | 0 | 2 | 3D9.1BF1A7885E |
| 85 | 0 | 2 | 3D9.1BF1A73F1E |
| 88 | 45 | 3 | 3D9.1BF1A9B578 |
| 89 | 45 | 1 | 3D9.1BF1A9919F |
| 91 | 45 | 2 | 3D9.1BF1A78FC4 |
| 92 | 45 | 1 | 3D9.1BF1A76D70 |
| 94 | 45 | 2 | 3D9.1BF1A9C00C |
| 96 | 45 | 2 | 3D9.1BF1CF51C6 |
| 100 | 45 | 4 | 3D9.1BF1A9C20F |
| 102 | 45 | 2 | 3D9.1BF1F7C65E |
| 104 | 45 | 2 | 3D9.1BF1A77453 |
| 106 | 0 | 2 | 3D9.1BF1A6C70C |
| 108 | 0 | 2 | 3D9.1BF1A1D513 |
| 110 | 0 | 2 | 3D9.1BF1A6C4CF |
| 112 | 0 | 2 | 3D9.1BF1A98396 |
| 114 | 45 | 2 | 3D9.1BF1A1D0F8 |
| 116 | 45 | 2 | 3D9.1BF22BF651 |
| 118 | 45 | 2 | 3D9.1BF1F8DA09 |
| 120 | 45 | 2 | 3D9.1BF22A8198 |
| 125 | 0 | 5 | 3D9.1BF1A9953C |

[a] Distance from previous tag as measured in the direction from 17 to 125 ft

[b] PIT-tags were tested after each antenna evaluation with a hand-held reader and replaced as needed

Appendix Table 2. Daily total PIT-tag sample time and detections for each salmonid species using the cylindrical and matrix pair trawl antenna systems at Jones Beach, 2008.

| Date | Total time underway (h) | Pit-tag detections (N) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Unknown | Chinook salmon | Coho salmon | Steelhead | Sockeye salmon | Total |
| 7 Mar | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 8 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 9 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 10 Mar | 3.05 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 12 Mar | 5.43 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 14 Mar | 5.67 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 16 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 17 Mar | 5.93 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 19 Mar | 4.92 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 21 Mar | 5.18 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 23 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 24 Mar | 5.13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 26 Mar | 4.95 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 28 Mar | 5.38 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 30 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 31 Mar | 0 | -- | -- | -- | -- | -- | -- |
| 1 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 2 Apr | 2.83 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 Apr | 4.6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 Apr | 0.75 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 6 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 7 Apr | 4.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 9 Apr | 5.42 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 Apr | 2.08 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 Apr | 4.07 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 13 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 14 Apr | 5.33 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 Apr | 5.28 | 0 | 4 | 0 | 0 | 0 | 4 |
| 16 Apr | 6.17 | 0 | 1 | 0 | 1 | 0 | 2 |
| 17 Apr | 5.68 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 Apr | 5.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 20 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 21 Apr | 5.7 | 0 | 0 | 0 | 1 | 0 | 1 |

Appendix Table 2. Continued.

| Date | Total time underway (h) | Pit-tag detections (N) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Unknown | Chinook salmon | Coho salmon | Steelhead | Sockeye salmon | Total |
| 22 Apr | 4.15 | 0 | 0 | 0 | 1 | 0 | 1 |
| 23 Apr | 5.32 | 0 | 1 | 0 | 1 | 0 | 2 |
| 24 Apr | 5.52 | 0 | 0 | 0 | | | |
| 25 Apr | 6.28 | 1 | 1 | 0 | 85 | 0 | 87 |
| 26 Apr | 5.85 | 0 | 2 | 0 | 19 | 0 | 21 |
| 27 Apr | 0 | -- | -- | -- | -- | -- | -- |
| 28 Apr | 6.45 | 0 | 9 | 0 | 11 | 0 | 20 |
| 29 Apr | 5.2 | 0 | 22 | 0 | 4 | 0 | 26 |
| 30 Apr | 10.85 | 1 | 37 | 0 | 28 | 0 | 66 |
| 1 May | 11.68 | 3 | 29 | 0 | 84 | 0 | 116 |
| 2 May | 11.44 | 3 | 21 | 0 | 255 | 0 | 279 |
| 3 May | 10.76 | 0 | 34 | 0 | 61 | 0 | 95 |
| 4 May | 10.49 | 0 | 25 | 0 | 34 | 0 | 59 |
| 5 May | 6.2 | 0 | 39 | 0 | 43 | 0 | 82 |
| 6 May | 11.25 | 0 | 33 | 0 | 79 | 0 | 112 |
| 7 May | 10.33 | 0 | 65 | 0 | 68 | 0 | 133 |
| 8 May | 10.52 | 0 | 75 | 2 | 142 | 0 | 219 |
| 9 May | 12.2 | 0 | 92 | 0 | 86 | 0 | 178 |
| 10 May | 12.72 | 1 | 109 | 1 | 81 | 0 | 192 |
| 11 May | 13.33 | 2 | 141 | 1 | 327 | 1 | 472 |
| 12 May | 14.37 | 1 | 206 | 7 | 266 | 0 | 480 |
| 13 May | 23.02 | 1 | 251 | 5 | 424 | 0 | 681 |
| 14 May | 23.01 | 1 | 450 | 0 | 567 | 2 | 1020 |
| 15 May | 18.63 | 0 | 472 | 1 | 352 | 0 | 825 |
| 16 May | 19.88 | 0 | 552 | 9 | 284 | 0 | 845 |
| 17 May | 18.13 | 1 | 953 | 3 | 213 | 1 | 1171 |
| 18 May | 15.75 | 0 | 676 | 6 | 316 | 4 | 1002 |
| 19 May | 16.2 | 4 | 586 | 7 | 277 | 1 | 875 |
| 20 May | 3.87 | 1 | 175 | 1 | 77 | 5 | 259 |
| 21 May | 13.07 | 4 | 355 | 1 | 134 | 7 | 501 |
| 22 May | 9.85 | 1 | 284 | 4 | 100 | 12 | 401 |
| 23 May | 12.67 | 1 | 355 | 10 | 102 | 1 | 469 |
| 24 May | 10.07 | 0 | 200 | 3 | 61 | 7 | 271 |
| 25 May | 14.67 | 4 | 317 | 8 | 140 | 9 | 478 |
| 26 May | 6.28 | 3 | 239 | 6 | 73 | 11 | 332 |
| 27 May | 5.78 | 0 | 61 | 6 | 30 | 2 | 99 |
| 28 May | 13.98 | 1 | 289 | 15 | 77 | 12 | 394 |
| 29 May | 12.93 | 0 | 298 | 15 | 226 | 10 | 549 |
| 30 May | 6.97 | 3 | 131 | 8 | 62 | 2 | 206 |
| 31 May | 1.58 | 0 | 5 | 2 | 6 | 0 | 13 |
| 1 Jun | 12.4 | 1 | 139 | 19 | 71 | 2 | 232 |
| 2 Jun | 11.22 | 0 | 109 | 30 | 73 | 3 | 215 |
| 3 Jun | 9.07 | 0 | 39 | 10 | 38 | 3 | 90 |
| 4 Jun | 9.42 | 0 | 40 | 15 | 32 | 3 | 90 |
| 5 Jun | 10.3 | 1 | 55 | 7 | 52 | 4 | 119 |
| 6 Jun | 11.75 | 4 | 49 | 10 | 61 | 5 | 129 |
| 7 Jun | 11.73 | 1 | 65 | 10 | 86 | 1 | 163 |
| 8 Jun | 12.15 | 0 | 55 | 8 | 38 | 4 | 105 |

Appendix Table 2.  Continued.

| Date | Total time underway (h) | Pit-tag detections (N) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Unknown | Chinook salmon | Coho salmon | Steelhead | Sockeye salmon | Total |
| 9 Jun | 5.67 | 0 | 34 | 5 | 44 | 0 | 83 |
| 10 Jun | 5.93 | 0 | 16 | 5 | 19 | 0 | 40 |
| 11 Jun | 12.33 | 1 | 63 | 12 | 47 | 1 | 124 |
| 12 Jun | 11.55 | 0 | 42 | 6 | 21 | 2 | 71 |
| 13 Jun | 10.12 | 0 | 46 | 1 | 18 | 0 | 65 |
| 14 Jun | 8.57 | 2 | 31 | 2 | 11 | 3 | 49 |
| 15 Jun | 5.63 | 2 | 21 | 3 | 12 | 0 | 38 |
| 16 Jun | 6.53 | 0 | 33 | 2 | 6 | 0 | 41 |
| 17 Jun | 5.73 | 6 | 15 | 3 | 35 | 0 | 59 |
| 18 Jun | 5.4 | 0 | 26 | 2 | 11 | 1 | 40 |
| 19 Jun | 5.58 | 2 | 20 | 1 | 6 | 0 | 29 |
| 20 Jun | 5.23 | 0 | 16 | 1 | 4 | 0 | 21 |
| 21 Jun | 4.98 | 0 | 18 | 1 | 10 | 0 | 29 |
| 22 Jun | 6.17 | 0 | 22 | 2 | 5 | 0 | 29 |
| 23 Jun | 4.93 | 1 | 13 | 0 | 1 | 0 | 15 |
| 24 Jun | 5.42 | 2 | 24 | 0 | 5 | 0 | 31 |
| 25 Jun | 6.42 | 0 | 18 | 2 | 9 | 0 | 29 |
| 26 Jun | 6.52 | 1 | 58 | 0 | 2 | 2 | 63 |
| 27 Jun | 5.73 | 0 | 68 | 0 | 14 | 1 | 83 |
| 28 Jun | 5.88 | 1 | 59 | 1 | 1 | 0 | 62 |
| 29 Jun | 0 | -- | -- | -- | -- | -- | -- |
| 30 Jun | 5.22 | 0 | 46 | 0 | 2 | 0 | 48 |
| 1 Jul | 5.78 | 0 | 40 | 1 | 3 | 0 | 44 |
| 2 Jul | 5.27 | 0 | 16 | 0 | 3 | 0 | 19 |
| 3 Jul | 5.35 | 1 | 25 | 4 | 1 | 0 | 31 |
| 4 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 5 Jul | 3.22 | 0 | 7 | 0 | 0 | 0 | 7 |
| 6 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 7 Jul | 6.4 | 0 | 35 | 0 | 2 | 0 | 37 |
| 8 Jul | 5.92 | 0 | 44 | 3 | 1 | 0 | 48 |
| 9 Jul | 6.65 | 0 | 47 | 2 | 3 | 0 | 52 |
| 10 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 11 Jul | 6.55 | 0 | 95 | 2 | 3 | 0 | 100 |
| 12 Jul | 6.5 | 0 | 82 | 0 | 0 | 0 | 82 |
| 13 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 14 Jul | 6.82 | 1 | 74 | 0 | 1 | 0 | 76 |
| 15 Jul | 6.48 | 0 | 59 | 0 | 0 | 0 | 59 |
| 16 Jul | 6.1 | 1 | 56 | 0 | 0 | 0 | 57 |
| 17 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 18 Jul | 5.78 | 0 | 35 | 0 | 0 | 0 | 35 |
| 19 Jul | 6.7 | 1 | 79 | 0 | 0 | 0 | 80 |
| 20 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 21 Jul | 5.88 | 0 | 35 | 0 | 1 | 0 | 36 |
| 22 Jul | 6.98 | 0 | 64 | 0 | 0 | 0 | 64 |
| 23 Jul | 6.87 | 0 | 56 | 0 | 0 | 0 | 56 |
| 24 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 25 Jul | 5.67 | 0 | 53 | 0 | 0 | 0 | 53 |
| 26 Jul | 7 | 0 | 110 | 0 | 0 | 0 | 110 |
| 27 Jul | 0 | -- | -- | -- | -- | -- | -- |

Appendix Table 2.  Continued.

| Date | Total time underway (h) | Pit-tag detections (N) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Unknown | Chinook salmon | Coho salmon | Steelhead | Sockeye salmon | Total |
| 28 Jul | 6.62 | 0 | 66 | 0 | 0 | 0 | 66 |
| 29 Jul | 5.42 | 0 | 15 | 0 | 0 | 0 | 15 |
| 30 Jul | 5.98 | 0 | 52 | 0 | 0 | 0 | 52 |
| 31 Jul | 0 | -- | -- | -- | -- | -- | -- |
| 1 Aug | 6.25 | 0 | 18 | 0 | 0 | 0 | 18 |
| 2 Aug | 5.38 | 1 | 11 | 0 | 0 | 0 | 12 |
| 3 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 4 Aug | 6 | 0 | 16 | 0 | 0 | 0 | 16 |
| 5 Aug | 6.45 | 0 | 24 | 0 | 0 | 0 | 24 |
| 6 Aug | 5.62 | 0 | 15 | 0 | 0 | 0 | 15 |
| 7 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 8 Aug | 6.02 | 1 | 12 | 0 | 0 | 0 | 13 |
| 9 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 10 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 11 Aug | 6.42 | 0 | 8 | 0 | 0 | 0 | 8 |
| 12 Aug | 6.43 | 0 | 15 | 0 | 0 | 0 | 15 |
| 13 Aug | 5.3 | 0 | 11 | 0 | 0 | 0 | 11 |
| 14 Aug | 6.02 | 0 | 5 | 0 | 0 | 0 | 5 |
| 15 Aug | 6.03 | 0 | 8 | 0 | 0 | 0 | 8 |
| 16 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 17 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 18 Aug | 6.42 | 0 | 3 | 0 | 0 | 0 | 3 |
| 19 Aug | 0 | -- | -- | -- | -- | -- | -- |
| 20 Aug | 6.13 | 0 | 2 | 0 | 0 | 0 | 2 |
| 29 Sept-30 Oct | 59.59 | 0 | 3 | 0 | 0 | 0 | 3 |
| Totals | 1,035 | 68 | 10,132 | 291 | 5,950 | 122 | 16,563 |

Appendix Table 3. Matrix and cylindrical system detections during tandem sampling, 13-15 May 2008.

| Detection | Matrix | | | | Cylindrical | | | | Detections on Both Systems | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | Unknown | Chinook | Steelhead | Sockeye | Unknown | Chinook | Steelhead | Sockeye | Unknown | Chinook | Steelhead | Sockeye |
| 5/13/2008 | 1 | 32 | 108 | 0 | 3 | 24 | 34 | 0 | 0 | 4 | 6 | 0 |
| 5/14/2008 | 0 | 101 | 339 | 1 | 1 | 77 | 109 | 0 | 0 | 16 | 27 | 0 |
| 5/15/2008 | 0 | 40 | 94 | 0 | 0 | 42 | 49 | 0 | 0 | 10 | 13 | 0 |
| Species total | 1 | 173 | 541 | 1 | 4 | 143 | 192 | 0 | 0 | 30 | 46 | 0 |
| Overall total | 716 | | | | 339 | | | | 76 | | | |

Appendix Table 4. Combined daily total of impinged fish on the cylindrical and matrix antenna systems used in the upper Columbia River estuary, 2008.

| Date | Chinook salmon Yearling | Chinook salmon Subyearling | Coho salmon | Steelhead | Sockeye |
|---|---|---|---|---|---|
| 7 Mar | 0 | 0 | | | |
| 8 Mar | -- | -- | -- | -- | -- |
| 9 Mar | -- | -- | -- | -- | -- |
| 10 Mar | 0 | 0 | 0 | 0 | 0 |
| 11 Mar | -- | -- | -- | -- | -- |
| 12 Mar | 0 | 0 | 0 | 0 | 0 |
| 13 Mar | -- | -- | -- | -- | -- |
| 14 Mar | 0 | 0 | 0 | 0 | 0 |
| 15 Mar | -- | -- | -- | -- | -- |
| 16 Mar | -- | -- | -- | -- | -- |
| 17 Mar | 0 | 0 | 0 | 0 | 0 |
| 18 Mar | -- | -- | -- | -- | -- |
| 19 Mar | 0 | 0 | 0 | 0 | 0 |
| 20 Mar | -- | -- | -- | -- | -- |
| 21 Mar | 0 | 0 | 0 | 0 | 0 |
| 22 Mar | -- | -- | -- | -- | -- |
| 23 Mar | -- | -- | -- | -- | -- |
| 24 Mar | 0 | 0 | 0 | 0 | 0 |
| 25 Mar | -- | -- | -- | -- | -- |
| 26 Mar | 0 | 0 | 0 | 0 | 0 |
| 27 Mar | -- | -- | -- | -- | -- |
| 28 Mar | 0 | 0 | 0 | 0 | 0 |
| 29 Mar | -- | -- | -- | -- | -- |
| 30 Mar | -- | -- | -- | -- | -- |
| 31 Mar | -- | -- | -- | -- | -- |
| 1 Apr | -- | -- | -- | -- | -- |
| 2 Apr | 0 | 0 | 0 | 0 | 0 |
| 3 Apr | 0 | 0 | 0 | 0 | 0 |
| 4 Apr | 0 | 0 | 0 | 0 | 0 |
| 5 Apr | -- | -- | -- | -- | -- |
| 6 Apr | -- | -- | -- | -- | -- |
| 7 Apr | 0 | 0 | 0 | 0 | 0 |
| 8 Apr | -- | -- | -- | -- | -- |
| 9 Apr | 0 | 0 | 0 | 0 | 0 |
| 10 Apr | 0 | 0 | 0 | 0 | 0 |
| 11 Apr | 0 | 0 | 0 | 0 | 0 |
| 12 Apr | -- | -- | -- | -- | -- |
| 13 Apr | -- | -- | -- | -- | -- |
| 14 Apr | 0 | 0 | 0 | 0 | 0 |
| 15 Apr | 0 | 0 | 0 | 0 | 0 |
| 16 Apr | 1 | 0 | 0 | 0 | 0 |
| 17 Apr | -- | -- | -- | -- | -- |
| 18 Apr | 0 | 0 | 0 | 0 | 0 |
| 19 Apr | -- | -- | -- | -- | -- |
| 20 Apr | -- | -- | -- | -- | -- |
| 21 Apr | 0 | 0 | 0 | 0 | 0 |
| 22 Apr | -- | -- | -- | -- | -- |
| 23 Apr | 0 | 0 | 0 | 0 | 0 |

Appendix Table 4. Continued.

| Date | Chinook salmon Yearling | Chinook salmon Subyearling | Coho salmon | Steelhead | Sockeye |
|---|---|---|---|---|---|
| 24 Apr | -- | -- | -- | -- | -- |
| 25 Apr | 0 | 0 | 0 | 0 | 0 |
| 26 Apr | 0 | 0 | 0 | 0 | 0 |
| 27 Apr | -- | -- | -- | -- | -- |
| 28 Apr | 0 | 0 | 0 | 0 | 0 |
| 29 Apr | 0 | 0 | 0 | 0 | 0 |
| 30 Apr | 3 | 0 | 0 | 1 | 0 |
| 1 May | 0 | 0 | 0 | 0 | 0 |
| 2 May | 9 | 1 | 1 | 2 | |
| 3 May | 1 | 0 | 0 | 0 | 0 |
| 4 May | 2 | 0 | 0 | 0 | 0 |
| 5 May | 1 | 0 | 0 | 0 | 0 |
| 6 May | 2 | 0 | 0 | 0 | 0 |
| 7 May | 1 | 0 | 0 | 0 | 0 |
| 8 May | 3 | 0 | 1 | 0 | 0 |
| 9 May | 4 | 0 | 0 | 1 | 0 |
| 10 May | 3 | 0 | 1 | 0 | 0 |
| 11 May | 3 | 0 | 1 | 0 | 0 |
| 12 May | 4 | 0 | 1 | 1 | 0 |
| 13 May | 2 | 0 | 0 | 0 | 0 |
| 14 May | 14 | 2 | 3 | 2 | 0 |
| 15 May | 4 | 0 | 0 | 1 | 0 |
| 16 May | 3 | 1 | 0 | 0 | 0 |
| 17 May | 15 | 0 | 4 | 3 | 0 |
| 18 May | 4 | 1 | 1 | 1 | 0 |
| 19 May | 3 | 0 | 0 | 1 | 0 |
| 20 May | 0 | 0 | 0 | 0 | 0 |
| 21 May | 8 | 0 | 1 | 1 | 0 |
| 22 May | 6 | 0 | 1 | 0 | 0 |
| 23 May | 4 | 0 | 1 | 0 | 0 |
| 24 May | 1 | 0 | 0 | 0 | 0 |
| 25 May | 4 | 0 | 0 | 1 | 0 |
| 26 May | 2 | 0 | 0 | 0 | 0 |
| 27 May | 0 | 0 | 0 | 0 | 0 |
| 28 May | 2 | 0 | 0 | 0 | 0 |
| 29 May | 2 | 0 | 0 | 0 | 0 |
| 30 May | 2 | 0 | 0 | 0 | 0 |
| 31 May | 5 | 1 | 1 | 1 | 0 |
| 1 Jun | 0 | 0 | 0 | 0 | 0 |
| 2 Jun | 1 | 0 | 0 | 0 | 0 |
| 3 Jun | 1 | 0 | 0 | 0 | 0 |
| 4 Jun | 3 | 0 | 1 | 0 | 0 |
| 5 Jun | 0 | 0 | 0 | 0 | 0 |
| 6 Jun | 1 | 0 | 0 | 0 | 0 |
| 7 Jun | 6 | 1 | 1 | 1 | 0 |
| 8 Jun | 0 | 0 | 0 | 0 | 0 |
| 9 Jun | 2 | 0 | 0 | 0 | 0 |
| 10 Jun | 2 | 0 | 0 | 0 | 0 |

Appendix Table 4. Continued.

| Date | Chinook salmon Yearling | Chinook salmon Subyearling | Coho salmon | Steelhead | Sockeye |
|---|---|---|---|---|---|
| 11 Jun | 0 | 0 | 0 | 0 | 0 |
| 12 Jun | 1 | 0 | 0 | 0 | 0 |
| 13 Jun | 0 | 0 | 0 | 0 | 0 |
| 14 Jun | 0 | 0 | 0 | 0 | 0 |
| 15 Jun | 0 | 0 | 0 | 0 | 0 |
| 16 Jun | 0 | 0 | 0 | 0 | 0 |
| 17 Jun | 0 | 0 | 0 | 0 | 0 |
| 18 Jun | 0 | 0 | 0 | 0 | 0 |
| 19 Jun | 0 | 0 | 0 | 0 | 0 |
| 20 Jun | 0 | 0 | 0 | 0 | 0 |
| 21 Jun | 1 | 0 | 0 | 0 | 0 |
| 22 Jun | 0 | 0 | 0 | 0 | 0 |
| 23 Jun | 0 | 0 | 0 | 0 | 0 |
| 24 Jun | 0 | 0 | 0 | 0 | 0 |
| 25 Jun | 0 | 0 | 0 | 0 | 0 |
| 26 Jun | 0 | 0 | 0 | 0 | 0 |
| 27 Jun | 0 | 0 | 0 | 0 | 0 |
| 28 Jun | 0 | 0 | 0 | 0 | 0 |
| 29 Jun | -- | -- | -- | -- | -- |
| 30 Jun | 0 | 0 | 0 | 0 | 0 |
| 1 Jul | 0 | 0 | 0 | 0 | 0 |
| 2 Jul | 1 | 0 | 0 | 0 | 0 |
| 3 Jul | 0 | 0 | 0 | 0 | 0 |
| 4 Jul | -- | -- | -- | -- | -- |
| 5 Jul | 1 | 0 | 0 | 0 | 0 |
| 6 Jul | -- | -- | -- | -- | -- |
| 7 Jul | 0 | 0 | 0 | 0 | 0 |
| 8 Jul | 1 | 0 | 0 | 0 | 0 |
| 9 Jul | 0 | 0 | 0 | 0 | 0 |
| 10 Jul | -- | -- | -- | -- | -- |
| 11 Jul | 0 | 0 | 0 | 0 | 0 |
| 12 Jul | 0 | 0 | 0 | 0 | 0 |
| 13 Jul | -- | -- | -- | -- | -- |
| 14 Jul | 1 | 0 | 0 | 0 | 0 |
| 15 Jul | 0 | 0 | 0 | 0 | 0 |
| 16 Jul | 0 | 0 | 0 | 0 | 0 |
| 17 Jul | -- | -- | -- | -- | -- |
| 18 Jul | 0 | 0 | 0 | 0 | 0 |
| 19 Jul | 0 | 0 | 0 | 0 | 0 |
| 20 Jul | 0 | 0 | 0 | 0 | 0 |
| 21 Jul | -- | -- | -- | -- | -- |
| 22 Jul | 0 | 0 | 0 | 0 | 0 |
| 23 Jul | 0 | 0 | 0 | 0 | 0 |
| 24 Jul | -- | -- | -- | -- | -- |
| 25 Jul | 0 | 0 | 0 | 0 | 0 |
| 26 Jul | 4 | 2 | 1 | 1 | 0 |
| 27 Jul | -- | -- | -- | -- | -- |
| 28 Jul | 3 | 0 | 0 | 0 | 0 |
| 29 Jul | 0 | 0 | 0 | 0 | 0 |

Appendix Table 4. Continued.

| Date | Chinook salmon | | Coho salmon | Steelhead | Sockeye |
|---|---|---|---|---|---|
| | Yearling | Subyearling | | | |
| 30 Jul | 0 | 0 | 0 | 0 | 0 |
| 31 Jul | -- | -- | -- | -- | -- |
| 1 Aug | 0 | 0 | 0 | 0 | 0 |
| 2 Aug | 0 | 0 | 0 | 0 | 0 |
| 3 Aug | -- | -- | -- | -- | -- |
| 4 Aug | 4 | 0 | 0 | 1 | 0 |
| 5 Aug | 0 | 0 | 0 | 0 | 0 |
| 6 Aug | 0 | 0 | 0 | 0 | 0 |
| 7 Aug | -- | -- | -- | -- | -- |
| 8 Aug | 0 | 0 | 0 | 0 | 0 |
| 9 Aug | -- | -- | -- | -- | -- |
| 10 Aug | -- | -- | -- | -- | -- |
| 11 Aug | 0 | 0 | 0 | 0 | 0 |
| 12 Aug | 0 | 0 | 0 | 0 | 0 |
| 13 Aug | 0 | 0 | 0 | 0 | 0 |
| 14 Aug | 0 | 0 | 0 | 0 | 0 |
| 15 Aug | 0 | 0 | 0 | 0 | 0 |
| 16 Aug | -- | -- | -- | -- | -- |
| 17 Aug | -- | -- | -- | -- | -- |
| 18 Aug | 0 | 0 | 0 | 0 | 0 |
| 19 Aug | -- | -- | -- | -- | -- |
| 20 Aug | 1 | 0 | 0 | 0 | 0 |
| Total | 152 | 9 | 20 | 19 | 0 |

Appendix Table 5. Diel sampling of yearling Chinook salmon and steelhead using a PIT-tag detector surface pair-trawl at Jones Beach (Columbia River kilometer 75), 2008. Two-crew effort between 30 April and 14 June was rounded to the nearest tenth and presented as a decimal hour.

| | | Yearling Chinook salmon | | | | Steelhead | | | |
|---|---|---|---|---|---|---|---|---|---|
| Diel hour | Effort (h) | Hatchery (n) | Wild (n) | Hatchery (n/h) | Wild (n/h) | Hatchery (n) | Wild (n) | Hatchery (n/h) | Wild (n/h) |
| 0 | 29.8 | 431 | 56 | 14.4 | 1.9 | 135 | 51 | 4.5 | 1.7 |
| 1 | 21.5 | 414 | 45 | 19.3 | 2.1 | 93 | 38 | 4.3 | 1.8 |
| 2 | 6.0 | 241 | 20 | 40.3 | 3.3 | 31 | 14 | 5.2 | 2.3 |
| 3 | 4.0 | 232 | 19 | 58.0 | 4.8 | 23 | 14 | 5.8 | 3.5 |
| 4 | 3.8 | 100 | 12 | 26.2 | 3.1 | 15 | 15 | 3.9 | 3.9 |
| 5 | 3.5 | 105 | 9 | 30.3 | 2.6 | 7 | 5 | 2.0 | 1.4 |
| 6 | 22.0 | 425 | 61 | 19.3 | 2.8 | 141 | 77 | 6.4 | 3.5 |
| 7 | 33.4 | 556 | 81 | 16.7 | 2.4 | 301 | 134 | 9.0 | 4.0 |
| 8 | 35.9 | 506 | 75 | 14.1 | 2.1 | 337 | 137 | 9.4 | 3.8 |
| 9 | 36.1 | 478 | 76 | 13.3 | 2.1 | 369 | 118 | 10.2 | 3.3 |
| 10 | 37.5 | 492 | 69 | 13.1 | 1.8 | 342 | 126 | 9.1 | 3.4 |
| 11 | 34.5 | 351 | 46 | 10.2 | 1.3 | 391 | 127 | 11.3 | 3.7 |
| 12 | 19.0 | 333 | 52 | 17.6 | 2.7 | 401 | 107 | 21.1 | 5.6 |
| 13 | 10.0 | 271 | 32 | 27.1 | 3.2 | 278 | 79 | 27.8 | 7.9 |
| 14 | 3.5 | 90 | 8 | 25.8 | 2.3 | 80 | 33 | 23.0 | 9.5 |
| 15 | 0.2 | 0 | 0 | 0.0 | 0.0 | 6 | 2 | 40.0 | 13.3 |
| 16 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 |
| 17 | 0.5 | 0 | 0 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 |
| 18 | 9.2 | 11 | 3 | 1.2 | 0.3 | 22 | 17 | 2.4 | 1.9 |
| 19 | 17.8 | 27 | 16 | 1.5 | 0.9 | 66 | 27 | 3.7 | 1.5 |
| 20 | 37.2 | 261 | 59 | 7.0 | 1.6 | 326 | 122 | 8.8 | 3.3 |
| 21 | 42.0 | 620 | 93 | 14.8 | 2.2 | 326 | 117 | 7.8 | 2.8 |
| 22 | 41.9 | 462 | 78 | 11.0 | 1.9 | 146 | 72 | 3.5 | 1.7 |
| 23 | 40.0 | 508 | 62 | 12.7 | 1.6 | 145 | 64 | 3.6 | 1.6 |
| Total | 489 | 6,914 | 972 | -- | -- | 3,981 | 1,496 | -- | -- |

Appendix Table 6. Number of PIT-tagged yearling Chinook salmon loaded on transport barges at each of four dams and numbers detected in the estuary. LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental; MCN, McNary Dam. Transport dates 11 April - 17 August; trawl operation 7 March – 20 August, with intensive sampling 30 April - 14 June, 2008. Totals for the entire season are shown, excluding acoustic-tagged fish and fish released below our sample site.

| Release date | Numbers loaded at each dam and total fish loaded (n) | | | | | Percent detected from each dam and total numbers detected | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| and time | LGR | LGO | LMN | MCN | n | LGR | LGO | LMN | MCN | n | (%) |
| 11 Apr 16:40 | 233 | 0 | 0 | 0 | 233 | 0 | -- | -- | -- | 0 | 0 |
| 18 Apr 17:55 | 633 | 0 | 0 | 0 | 633 | 1.26 | -- | -- | -- | 8 | 1.3 |
| 23 Apr 7:10 | 3,402 | 0 | 0 | 0 | 3,402 | 0.73 | -- | -- | -- | 25 | 0.7 |
| 25 Apr 17:05 | 709 | 0 | 0 | 0 | 709 | 1.83 | -- | -- | -- | 13 | 1.8 |
| 30 Apr 5:15 | 3,348 | 0 | 0 | 0 | 3,348 | 1.08 | -- | -- | -- | 36 | 1.1 |
| 02 May 17:10 | 1,140 | 0 | 0 | 0 | 1,140 | 0.7 | -- | -- | -- | 8 | 0.7 |
| 03 May 19:50 | 3,277 | 0 | 0 | 0 | 3,277 | 0.49 | -- | -- | -- | 16 | 0.5 |
| 04 May 19:55 | 2,902 | 0 | 0 | 0 | 2,902 | 0.96 | -- | -- | -- | 28 | 1 |
| 05 May 23:35 | 1,613 | 0 | 0 | 0 | 1,613 | 0.81 | -- | -- | -- | 13 | 0.8 |
| 06 May 19:57 | 5,950 | 0 | 0 | 0 | 5,950 | 0.81 | -- | -- | -- | 48 | 0.8 |
| 07 May 19:25 | 3,904 | 0 | 0 | 0 | 3,904 | 1 | -- | -- | -- | 39 | 1 |
| 08 May 19:15 | 4,418 | 0 | 0 | 0 | 4,418 | 1.29 | -- | -- | -- | 57 | 1.3 |
| 09 May 19:40 | 6,521 | 0 | 0 | 0 | 6,521 | 1.7 | -- | -- | -- | 111 | 1.7 |
| 10 May 22:05 | 5,803 | 532 | 0 | 0 | 6,335 | 1.69 | 2.44 | -- | -- | 111 | 1.8 |
| 12 May 0:35 | 4,491 | 2,383 | 0 | 0 | 6,874 | 1.65 | 2.06 | -- | -- | 123 | 1.8 |
| 12 May 21:10 | 4,756 | 2,866 | 0 | 0 | 7,622 | 1.72 | 2.69 | -- | -- | 159 | 2.1 |
| 13 May 23:00 | 11,021 | 2,948 | 0 | 0 | 13,969 | 2.22 | 3.43 | -- | -- | 346 | 2.5 |
| 15 May 0:50 | 3,282 | 1,992 | 616 | 0 | 5,890 | 3.26 | 4.57 | 7.14 | -- | 242 | 4.1 |
| 16 May 6:20 | 2,414 | 2,122 | 1,026 | 0 | 5,562 | 2.82 | 3.35 | 4 | -- | 180 | 3.2 |
| 16 May 22:40 | 2,560 | 1,264 | 307 | 0 | 4,131 | 2.81 | 3.48 | 1.63 | -- | 121 | 2.9 |
| 17 May 22:30 | 1,405 | 1,866 | 398 | 0 | 3,669 | 1.07 | 1.13 | 1.51 | -- | 42 | 1.1 |
| 18 May 22:45 | 1,591 | 1,371 | 465 | 0 | 3,427 | 0.75 | 0.22 | 0.22 | -- | 16 | 0.5 |
| 19 May 20:30 | 2,846 | 2,616 | 711 | 0 | 6,173 | 1.48 | 1.99 | 2.81 | -- | 114 | 1.8 |
| 20 May 18:20 | 9,988 | 2,294 | 0 | 0 | 12,282 | 0.84 | 1.26 | -- | -- | 113 | 0.9 |

Appendix Table 6.  Continued.

| Release date and time | Numbers loaded at each dam and total fish loaded (n) | | | | | Percent detected from each dam and total numbers detected | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR | LGO | LMN | MCN | n | LGR | LGO | LMN | MCN | n | (%) |
| 21 May 19:30 | 1,175 | 3,326 | 0 | 0 | 4,501 | 0.85 | 1.86 | -- | -- | 72 | 1.6 |
| 22 May 18:05 | 492 | 2,131 | 0 | 0 | 2,623 | 1.02 | 0.38 | -- | -- | 13 | 0.5 |
| 23 May 19:10 | 692 | 1,457 | 0 | 0 | 2,149 | 1.73 | 2.47 | -- | -- | 48 | 2.2 |
| 24 May 20:00 | 369 | 1,292 | 0 | 0 | 1,661 | 1.08 | 2.01 | -- | -- | 30 | 1.8 |
| 25 May 18:40 | 531 | 958 | 710 | 0 | 2,199 | 0.19 | 0.42 | 0.56 | -- | 9 | 0.4 |
| 26 May 19:25 | 184 | 839 | 497 | 0 | 1,520 | 1.63 | 1.79 | 1.61 | -- | 26 | 1.7 |
| 27 May 19:15 | 3,664 | 536 | 277 | 0 | 4,477 | 1.2 | 2.61 | 2.17 | -- | 64 | 1.4 |
| 28 May 20:00 | 145 | 657 | 345 | 0 | 1,147 | 0.69 | 2.28 | 3.19 | -- | 27 | 2.4 |
| 29 May 22:00 | 367 | 621 | 265 | 0 | 1,253 | 0.82 | 0.16 | 0 | -- | 4 | 0.3 |
| 30 May 17:55 | 289 | 481 | 215 | 0 | 985 | 3.11 | 0.83 | 3.26 | -- | 20 | 2 |
| 31 May 17:45 | 328 | 513 | 332 | 0 | 1,173 | 0.3 | 2.73 | 1.51 | -- | 20 | 1.7 |
| 01 Jun 19:45 | 185 | 513 | 234 | 0 | 932 | 1.08 | 1.36 | 0.85 | -- | 11 | 1.2 |
| 02 Jun 18:40 | 78 | 291 | 200 | 0 | 569 | 2.56 | 2.06 | 1.5 | -- | 11 | 1.9 |
| 03 Jun 18:15 | 68 | 371 | 188 | 0 | 627 | 0 | 2.43 | 3.19 | -- | 15 | 2.4 |
| 05 Jun 2:01 | 300 | 293 | 214 | 0 | 807 | 3 | 0 | 0.47 | -- | 10 | 1.2 |
| 05 Jun 19:15 | 282 | 279 | 169 | 0 | 730 | 1.77 | 3.23 | 2.96 | -- | 19 | 2.6 |
| 07 Jun 19:15 | 801 | 288 | 279 | 0 | 1,368 | 0.75 | 2.78 | 2.87 | -- | 22 | 1.6 |
| 09 Jun 18:55 | 206 | 199 | 107 | 0 | 512 | 0.97 | 0.5 | 6.54 | -- | 10 | 2 |
| 11 Jun 19:00 | 75 | 197 | 30 | 0 | 302 | 0 | 2.03 | 0 | -- | 4 | 1.3 |
| 13 Jun 18:05 | 79 | 150 | 55 | 0 | 284 | 1.27 | 1.33 | 3.64 | -- | 5 | 1.8 |
| 15 Jun 18:45 | 52 | 93 | 41 | 0 | 186 | 1.92 | 1.08 | 2.44 | -- | 3 | 1.6 |
| 17 Jun 20:55 | 83 | 52 | 16 | 0 | 151 | 1.2 | 0 | 0 | -- | 1 | 0.7 |
| 19 Jun 18:25 | 66 | 81 | 19 | 0 | 166 | 0 | 0 | 5.26 | -- | 1 | 0.6 |
| 21 Jun 19:45 | 23 | 95 | 57 | 0 | 175 | 4.35 | 1.05 | 0 | -- | 2 | 1.1 |
| 22 Jun 20:20 | 26 | 92 | 27 | 0 | 145 | 0 | 4.35 | 0 | -- | 4 | 2.8 |
| 25 Jun 19:15 | 13 | 77 | 14 | 0 | 104 | 15.38 | 2.6 | 0 | -- | 4 | 3.8 |
| 27 Jun 21:10 | 14 | 51 | 5 | 0 | 70 | 0 | 0 | 0 | -- | 0 | 0 |
| 29 Jun 17:55 | 17 | 28 | 6 | 0 | 51 | 0 | 0 | 0 | -- | 0 | 0 |
| 01 Jul 17:05 | 15 | 39 | 3 | 0 | 57 | 0 | 0 | 0 | -- | 0 | 0 |

Appendix Table 6. Continued.

| Release date and time | Numbers loaded at each dam and total fish loaded (n) LGR | LGO | LMN | MCN | n | Percent detected from each dam and total numbers detected LGR | LGO | LMN | MCN | n | (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 03 Jul 18:45 | 25 | 16 | 4 | 0 | 45 | 0 | 0 | 0 | -- | 0 | 0 |
| 05 Jul 18:10 | 30 | 22 | 9 | 0 | 61 | 0 | 4.55 | 0 | -- | 1 | 1.6 |
| 07 Jul 19:40 | 34 | 22 | 3 | 0 | 59 | 5.88 | 4.55 | 0 | -- | 3 | 5.1 |
| 09 Jul 17:45 | 8 | 12 | 6 | 0 | 26 | 0 | 0 | 0 | -- | 0 | 0 |
| 11 Jul 19:30 | 7 | 16 | 1 | 0 | 24 | 0 | 0 | 0 | -- | 0 | 0 |
| 13 Jul 18:50 | 4 | 8 | 4 | 0 | 16 | 0 | 0 | 0 | -- | 0 | 0 |
| 15 Jul 19:50 | 9 | 3 | 1 | 0 | 13 | 0 | 0 | 0 | -- | 0 | 0 |
| 18 Jul 2:23 | 2 | 0 | 0 | 0 | 2 | 0 | -- | -- | -- | 0 | 0 |
| 20 Jul 4:30 | 6 | 0 | 2 | 2 | 10 | 0 | -- | 0 | 0 | 0 | 0 |
| 22 Jul 3:10 | 7 | 6 | 1 | 1 | 15 | 14.29 | 0 | 0 | 0 | 1 | 6.7 |
| 24 Jul 5:05 | 5 | 2 | 0 | 4 | 11 | 0 | 0 | -- | 0 | 0 | 0 |
| 26 Jul 3:40 | 4 | 2 | 0 | 0 | 6 | 0 | 0 | -- | -- | 0 | 0 |
| 28 Jul 5:05 | 4 | 6 | 0 | 0 | 10 | 0 | 0 | -- | -- | 0 | 0 |
| 30 Jul 5:00 | 1 | 2 | 2 | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 01 Aug 3:50 | 4 | 2 | 0 | 0 | 6 | 0 | 0 | -- | -- | 0 | 0 |
| 03 Aug 1:05 | 3 | 0 | 0 | 0 | 3 | 0 | -- | -- | -- | 0 | 0 |
| 05 Aug 4:15 | 2 | 0 | 0 | 0 | 2 | 0 | -- | -- | -- | 0 | 0 |
| 07 Aug 1:35 | 2 | 1 | 0 | 1 | 4 | 0 | 0 | -- | 0 | 0 | 0 |
| 09 Aug 4:25 | 1 | 1 | 0 | 2 | 4 | 0 | 0 | -- | 0 | 0 | 0 |
| 11 Aug 4:40 | 1 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | -- | 0 | 0 |
| 13 Aug 3:00 | 0 | 0 | 0 | 1 | 1 | -- | -- | -- | 0 | 0 | 0 |
| 17 Aug 3:50 | 0 | 1 | 1 | 0 | 2 | -- | 0 | 0 | -- | 0 | 0 |
| Totals | 98,985 | 38,377 | 7,863 | 12 | 145,237 | 1.44 | 2.1 | 2.47 | 0 | 2,429 | 1.67 |

Appendix Table 7. Numbers of PIT-tagged steelhead loaded to barges and numbers subsequently detected in the estuary. Abbreviations: LGR, Lower Granite; LGO, Little Goose; LMN, Lower Monumental; MCN, McNary Dam. Transport dates were 11 April-18 July; trawl operation was 7 March–20 August, with intensive sampling 30 April-14 June, 2008. Totals for the entire season are shown, excluding acoustic-tagged fish and fish released below our sample site.

| Release date | Numbers loaded at each dam and total fish loaded (n) | | | | | Percent detected from each dam and total numbers detected (n) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| and time | LGR | LGO | LMN | MCN | n | LGR | LGO | LMN | MCN | n | (%) |
| 11 Apr 16:40 | 10 | 0 | 0 | 0 | 10 | | -- | -- | -- | 0 | 0 |
| 18 Apr 17:55 | 81 | 0 | 0 | 0 | 81 | 2.47 | -- | -- | -- | 2 | 2.5 |
| 23 Apr 7:10 | 7,576 | 0 | 0 | 0 | 7,576 | 1.7 | -- | -- | -- | 129 | 1.7 |
| 25 Apr 17:05 | 868 | 0 | 0 | 0 | 868 | 0.58 | -- | -- | -- | 5 | 0.6 |
| 30 Apr 5:15 | 10,787 | 0 | 0 | 0 | 10,787 | 3 | -- | -- | -- | 324 | 3 |
| 02 May 17:10 | 279 | 0 | 0 | 0 | 279 | 2.51 | -- | -- | -- | 7 | 2.5 |
| 03 May 19:50 | 1,061 | 0 | 0 | 0 | 1,061 | 4.05 | -- | -- | -- | 43 | 4.1 |
| 04 May 19:55 | 1,141 | 0 | 0 | 0 | 1,141 | 1.14 | -- | -- | -- | 13 | 1.1 |
| 05 May 23:35 | 841 | 0 | 0 | 0 | 841 | 1.78 | -- | -- | -- | 15 | 1.8 |
| 06 May 19:57 | 5,636 | 0 | 0 | 0 | 5,636 | 1.12 | -- | -- | -- | 63 | 1.1 |
| 07 May 19:25 | 1,556 | 0 | 0 | 0 | 1,556 | 1.16 | -- | -- | -- | 18 | 1.2 |
| 08 May 19:15 | 628 | 0 | 0 | 0 | 628 | 2.71 | -- | -- | -- | 17 | 2.7 |
| 09 May 19:40 | 1,298 | 0 | 0 | 0 | 1,298 | 6.39 | -- | -- | -- | 83 | 6.4 |
| 10 May 22:05 | 1,372 | 261 | 0 | 0 | 1,633 | 2.04 | 1.53 | -- | -- | 32 | 2 |
| 12 May 0:35 | 1,651 | 1,057 | 0 | 0 | 2,708 | 3.27 | 2.08 | -- | -- | 76 | 2.8 |
| 12 May 21:10 | 939 | 1,954 | 0 | 0 | 2,893 | 4.05 | 6.76 | -- | -- | 170 | 5.9 |
| 13 May 23:00 | 4,592 | 751 | 0 | 0 | 5,343 | 1.5 | 2 | -- | -- | 84 | 1.6 |
| 15 May 0:50 | 1,255 | 762 | 184 | 0 | 2,201 | 2.63 | 2.49 | 4.89 | -- | 61 | 2.8 |
| 16 May 6:20 | 453 | 494 | 247 | 0 | 1,194 | 1.77 | 1.82 | 1.62 | -- | 21 | 1.8 |
| 16 May 22:40 | 1,059 | 334 | 109 | 0 | 1,502 | 6.61 | 5.39 | 4.59 | -- | 93 | 6.2 |

Appendix Table 7.  Continued.

| Release date and time | Numbers loaded at each dam and total fish loaded (n) | | | | | Percent detected from each dam and total numbers detected (n) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR | LGO | LMN | MCN | n | LGR | LGO | LMN | MCN | n | (%) |
| 17 May 22:30 | 514 | 1,387 | 203 | 0 | 2,104 | 3.89 | 2.09 | 1.97 | -- | 53 | 2.5 |
| 18 May 22:45 | 1,024 | 1,242 | 445 | 0 | 2,711 | 0.2 | 0.16 | 0 | -- | 4 | 0.1 |
| 19 May 20:30 | 1,143 | 1,241 | 407 | 0 | 2,791 | 1.22 | 0.64 | 1.72 | -- | 29 | 1 |
| 20 May 18:20 | 6,279 | 952 | 0 | 0 | 7,231 | 0.76 | 1.37 | -- | -- | 61 | 0.8 |
| 21 May 19:30 | 789 | 1,385 | 0 | 0 | 2,174 | 0.51 | 0.58 | -- | -- | 12 | 0.6 |
| 22 May 18:05 | 569 | 1,107 | 0 | 0 | 1,676 | 0.53 | 0.27 | -- | -- | 6 | 0.4 |
| 23 May 19:10 | 1,176 | 779 | 0 | 0 | 1,955 | 1.96 | 1.28 | -- | -- | 33 | 1.7 |
| 24 May 20:00 | 859 | 378 | 0 | 0 | 1,237 | 1.4 | 0.26 | -- | -- | 13 | 1.1 |
| 25 May 18:40 | 809 | 221 | 312 | 0 | 1,342 | 0 | 1.36 | 0 | -- | 3 | 0.2 |
| 26 May 19:25 | 158 | 244 | 168 | 0 | 570 | 1.9 | 2.05 | 1.19 | -- | 10 | 1.8 |
| 27 May 19:15 | 9,558 | 163 | 120 | 0 | 9,841 | 1.37 | 1.23 | 0 | -- | 133 | 1.4 |
| 28 May 20:00 | 160 | 199 | 176 | 0 | 535 | 0.63 | 1.01 | 1.14 | -- | 5 | 0.9 |
| 29 May 22:00 | 793 | 176 | 160 | 0 | 1,129 | 0.38 | 0.57 | 0 | -- | 4 | 0.4 |
| 30 May 17:55 | 786 | 152 | 108 | 0 | 1,046 | 0.76 | 0.66 | 0 | -- | 7 | 0.7 |
| 31 May 17:45 | 1,011 | 194 | 147 | 0 | 1,352 | 0.89 | 0.52 | 0 | -- | 10 | 0.7 |
| 01 Jun 19:45 | 886 | 173 | 119 | 0 | 1,178 | 0.79 | 1.73 | 0 | -- | 10 | 0.8 |
| 02 Jun 18:40 | 98 | 219 | 118 | 0 | 435 | 3.06 | 1.37 | 0.85 | -- | 7 | 1.6 |
| 03 Jun 18:15 | 49 | 192 | 99 | 0 | 340 | 0 | 1.04 | 6.06 | -- | 8 | 2.4 |
| 05 Jun 2:01 | 459 | 98 | 104 | 0 | 661 | 1.09 | 2.04 | 0 | -- | 7 | 1.1 |
| 05 Jun 19:15 | 525 | 89 | 51 | 0 | 665 | 2.29 | 1.12 | 0 | -- | 13 | 2 |
| 07 Jun 19:15 | 589 | 179 | 142 | 0 | 910 | 3.74 | 2.79 | 1.41 | -- | 29 | 3.2 |
| 09 Jun 18:55 | 434 | 147 | 79 | 0 | 660 | 3.23 | 1.36 | 2.53 | -- | 18 | 2.7 |
| 11 Jun 19:00 | 211 | 90 | 57 | 0 | 358 | 1.42 | 0 | 1.75 | -- | 4 | 1.1 |

Appendix Table 7.  Continued.

| Release date and time | Numbers loaded at each dam and total fish loaded (n) | | | | | Percent detected from each dam and total numbers detected | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LGR | LGO | LMN | MCN | n | LGR | LGO | LMN | MCN | n | (%) |
| 13 Jun 18:05 | 429 | 43 | 35 | 0 | 507 | 0.7 | 0 | 0 | -- | 3 | 0.6 |
| 15 Jun 18:45 | 160 | 47 | 16 | 0 | 223 | 6.88 | 6.38 | 6.25 | -- | 15 | 6.7 |
| 17 Jun 20:55 | 27 | 33 | 14 | 0 | 74 | 7.41 | 0 | 0 | -- | 2 | 2.7 |
| 19 Jun 18:25 | 13 | 14 | 13 | 0 | 40 | 0 | 0 | 0 | -- | 0 | 0 |
| 21 Jun 19:45 | 11 | 23 | 10 | 0 | 44 | 0 | 4.35 | 0 | -- | 1 | 2.3 |
| 22 Jun 20:20 | 9 | 23 | 10 | 0 | 42 | 22.22 | 8.7 | 10 | -- | 5 | 11.9 |
| 25 Jun 19:15 | 11 | 16 | 2 | 0 | 29 | 0 | 0 | 0 | -- | 0 | 0 |
| 27 Jun 21:10 | 5 | 25 | 5 | 0 | 35 | 0 | 0 | 0 | -- | 0 | 0 |
| 29 Jun 17:55 | 2 | 9 | 3 | 0 | 14 | 0 | 0 | 0 | -- | 0 | 0 |
| 01 Jul 17:05 | 7 | 11 | 1 | 0 | 19 | 0 | 0 | 0 | -- | 0 | 0 |
| 03 Jul 18:45 | 5 | 3 | 0 | 0 | 8 | 0 | 0 | -- | -- | 0 | 0 |
| 05 Jul 18:10 | 4 | 4 | 1 | 0 | 9 | 25 | 25 | 0 | -- | 2 | 22.2 |
| 07 Jul 19:40 | 2 | 6 | 0 | 0 | 8 | 50 | 16.67 | -- | -- | 2 | 25 |
| 09 Jul 17:45 | 0 | 3 | 0 | 0 | 3 | -- | 0 | -- | -- | 0 | 0 |
| 11 Jul 19:30 | 0 | 1 | 0 | 0 | 1 | -- | 0 | -- | -- | 0 | 0 |
| 15 Jul 19:50 | 0 | 2 | 0 | 0 | 2 | -- | 0 | -- | -- | 0 | 0 |
| 18 Jul 2:23 | 1 | 0 | 0 | 0 | 1 | 0 | -- | -- | -- | 0 | 0 |
| Totals | 72,648 | 16,883 | 3,665 | 0 | 93,196 | 1.91 | 1.98 | 1.28 | 0 | 1,765 | 1.89 |

Appendix Table 8. Detections in the Columbia River estuary of PIT-tagged juvenile Chinook salmon and steelhead previously detected at Bonneville Dam, 2008. At Bonneville Dam, the juvenile bypass system operated 3 Mar-18 Dec and the corner collector operated 6 Mar-9 Sep; trawl operation 7 Mar-20 Aug and 29 Sep-27 Oct, intensive sampling 30 Apr-14 Jun. Season totals are shown, including all release sites.

| Detection date at Bonneville Dam | Bonneville Dam detections | | Jones Beach detections | | Jones Beach detections previously detected at Bonneville (%) | |
|---|---|---|---|---|---|---|
| | Chinook salmon (n) | Steelhead (n) | Chinook salmon (n) | Steelhead (n) | Chinook salmon | Steelhead |
| 16 Feb-6 Mar | 9 | 0 | 0 | -- | 0 | -- |
| 7 Mar | 120 | 0 | 1 | -- | 0.83 | -- |
| 8 Mar | 192 | 0 | 1 | -- | 0.52 | -- |
| 9 Mar | 141 | 0 | 0 | -- | 0 | -- |
| 10 Mar | 41 | 0 | 0 | -- | 0 | -- |
| 11 Mar | 16 | 1 | 0 | 0 | 0 | 0 |
| 12 Mar | 12 | 0 | 0 | -- | 0 | -- |
| 13 Mar | 10 | 0 | 0 | -- | 0 | -- |
| 14 Mar | 0 | 0 | -- | -- | -- | -- |
| 15 Mar | 2 | 0 | 0 | -- | 0 | -- |
| 16 Mar | 2 | 0 | 0 | -- | 0 | -- |
| 17 Mar | 2 | 0 | 0 | -- | 0 | -- |
| 18 Mar | 3 | 0 | 0 | -- | 0 | -- |
| 19 Mar | 2 | 0 | 0 | -- | 0 | -- |
| 20 Mar | 1 | 0 | 0 | -- | 0 | -- |
| 21 Mar | 2 | 0 | 0 | -- | 0 | -- |
| 22 Mar | 0 | 0 | -- | -- | -- | -- |
| 23 Mar | 0 | 0 | -- | -- | -- | -- |
| 24 Mar | 1 | 0 | 0 | -- | 0 | -- |
| 25 Mar | 1 | 0 | 0 | -- | 0 | -- |
| 26 Mar | 1 | 0 | 0 | -- | 0 | -- |
| 27 Mar | 1 | 0 | 0 | -- | 0 | -- |
| 28 Mar | 1 | 1 | 0 | 0 | 0 | 0 |
| 29 Mar | 0 | 0 | -- | -- | -- | -- |
| 30 Mar | 0 | 0 | -- | -- | -- | -- |
| 31 Mar | 2 | 1 | 0 | 0 | 0 | 0 |
| 1 Apr | 0 | 0 | -- | -- | -- | -- |
| 2 Apr | 3 | 0 | 0 | -- | 0 | -- |
| 3 Apr | 1 | 3 | 0 | 0 | 0 | 0 |
| 4 Apr | 3 | 0 | 0 | -- | 0 | -- |
| 5 Apr | 3 | 2 | 0 | 0 | 0 | 0 |
| 6 Apr | 4 | 2 | 0 | 0 | 0 | 0 |
| 7 Apr | 1 | 10 | 0 | 0 | 0 | 0 |
| 8 Apr | 1 | 7 | 0 | 0 | 0 | 0 |
| 9 Apr | 0 | 3 | -- | 0 | -- | 0 |
| 10 Apr | 2 | 2 | 0 | 0 | 0 | 0 |
| 11 Apr | 55 | 2 | 0 | 0 | 0 | 0 |
| 12 Apr | 115 | 3 | 0 | 0 | 0 | 0 |
| 13 Apr | 124 | 3 | 0 | 0 | 0 | 0 |

Appendix Table 8. Continued.

| Detection date at Bonneville Dam | Bonneville Dam detections | | Jones Beach detections | | Jones Beach detections previously detected at Bonneville (%) | |
|---|---|---|---|---|---|---|
| | Chinook salmon (n) | Steelhead (n) | Chinook salmon (n) | Steelhead (n) | Chinook salmon | Steelhead |
| 14 Apr | 71 | 7 | 1 | 0 | 1.41 | 0 |
| 15 Apr | 85 | 6 | 1 | 0 | 1.18 | 0 |
| 16 Apr | 83 | 2 | 0 | 0 | 0 | 0 |
| 17 Apr | 65 | 8 | 1 | 0 | 1.54 | 0 |
| 18 Apr | 88 | 6 | 0 | 0 | 0 | 0 |
| 19 Apr | 104 | 4 | 0 | 0 | 0 | 0 |
| 20 Apr | 126 | 9 | 1 | 0 | 0.79 | 0 |
| 21 Apr | 104 | 4 | 0 | 0 | 0 | 0 |
| 22 Apr | 127 | 6 | 4 | 1 | 3.15 | 16.67 |
| 23 Apr | 153 | 7 | 1 | 0 | 0.65 | 0 |
| 24 Apr | 185 | 20 | 1 | 0 | 0.54 | 0 |
| 25 Apr | 187 | 45 | 1 | 1 | 0.53 | 2.22 |
| 26 Apr | 261 | 33 | 1 | 1 | 0.38 | 3.03 |
| 27 Apr | 198 | 64 | 0 | 2 | 0 | 3.13 |
| 28 Apr | 188 | 131 | 5 | 5 | 2.66 | 3.82 |
| 29 Apr | 242 | 282 | 3 | 8 | 1.24 | 2.84 |
| 30 Apr | 219 | 307 | 2 | 10 | 0.91 | 3.26 |
| 1 May | 275 | 292 | 4 | 7 | 1.45 | 2.4 |
| 2 May | 229 | 199 | 3 | 7 | 1.31 | 3.52 |
| 3 May | 414 | 200 | 8 | 3 | 1.93 | 1.5 |
| 4 May | 349 | 358 | 1 | 10 | 0.29 | 2.79 |
| 5 May | 481 | 645 | 6 | 8 | 1.25 | 1.24 |
| 6 May | 617 | 1328 | 5 | 32 | 0.81 | 2.41 |
| 7 May | 657 | 1018 | 9 | 30 | 1.37 | 2.95 |
| 8 May | 736 | 1015 | 8 | 19 | 1.09 | 1.87 |
| 9 May | 1025 | 1555 | 20 | 72 | 1.95 | 4.63 |
| 10 May | 844 | 1230 | 19 | 73 | 2.25 | 5.93 |
| 11 May | 1038 | 2109 | 36 | 140 | 3.47 | 6.64 |
| 12 May | 1019 | 1090 | 26 | 89 | 2.55 | 8.17 |
| 13 May | 1734 | 1642 | 56 | 116 | 3.23 | 7.06 |
| 14 May | 1826 | 1507 | 53 | 72 | 2.9 | 4.78 |
| 15 May | 2477 | 1249 | 158 | 49 | 6.38 | 3.92 |
| 16 May | 2443 | 1101 | 104 | 37 | 4.26 | 3.36 |
| 17 May | 2511 | 1023 | 91 | 49 | 3.62 | 4.79 |
| 18 May | 2160 | 902 | 25 | 16 | 1.16 | 1.77 |
| 19 May | 2313 | 707 | 14 | 6 | 0.61 | 0.85 |
| 20 May | 1006 | 552 | 15 | 8 | 1.49 | 1.45 |
| 21 May | 900 | 575 | 10 | 5 | 1.11 | 0.87 |
| 22 May | 782 | 597 | 7 | 5 | 0.9 | 0.84 |
| 23 May | 513 | 637 | 12 | 4 | 2.34 | 0.63 |
| 24 May | 1341 | 693 | 26 | 5 | 1.94 | 0.72 |
| 25 May | 1806 | 764 | 5 | 1 | 0.28 | 0.13 |
| 26 May | 1447 | 561 | 28 | 6 | 1.94 | 1.07 |
| 27 May | 1469 | 545 | 24 | 2 | 1.63 | 0.37 |

Appendix Table 8. Continued.

| Detection date at Bonneville Dam | Bonneville Dam detections | | Jones Beach detections | | Jones Beach detections previously detected at Bonneville (%) | |
|---|---|---|---|---|---|---|
| | Chinook salmon (n) | Steelhead (n) | Chinook salmon (n) | Steelhead (n) | Chinook salmon | Steelhead |
| 28 May | 669 | 516 | 10 | 14 | 1.49 | 2.71 |
| 29 May | 326 | 231 | 0 | 0 | 0 | 0 |
| 30 May | 560 | 259 | 5 | 2 | 0.89 | 0.77 |
| 31 May | 304 | 139 | 3 | 3 | 0.99 | 2.16 |
| 1 Jun | 110 | 119 | 0 | 4 | 0 | 3.36 |
| 2 Jun | 108 | 65 | 2 | 0 | 1.85 | 0 |
| 3 Jun | 100 | 77 | 7 | 2 | 7 | 2.6 |
| 4 Jun | 121 | 179 | 1 | 5 | 0.83 | 2.79 |
| 5 Jun | 95 | 121 | 0 | 3 | 0 | 2.48 |
| 6 Jun | 97 | 136 | 2 | 7 | 2.06 | 5.15 |
| 7 Jun | 149 | 109 | 2 | 0 | 1.34 | 0 |
| 8 Jun | 255 | 76 | 0 | 1 | 0 | 1.32 |
| 9 Jun | 185 | 116 | 5 | 5 | 2.7 | 4.31 |
| 10 Jun | 197 | 106 | 7 | 6 | 3.55 | 5.66 |
| 11 Jun | 146 | 45 | 3 | 1 | 2.05 | 2.22 |
| 12 Jun | 110 | 32 | 2 | 2 | 1.82 | 6.25 |
| 13 Jun | 152 | 43 | 1 | 1 | 0.66 | 2.33 |
| 14 Jun | 193 | 58 | 6 | 1 | 3.11 | 1.72 |
| 15 Jun | 190 | 64 | 0 | 1 | 0 | 1.56 |
| 16 Jun | 206 | 45 | 2 | 1 | 0.97 | 2.22 |
| 17 Jun | 245 | 27 | 3 | 0 | 1.22 | 0 |
| 18 Jun | 273 | 40 | 0 | 0 | 0 | 0 |
| 19 Jun | 282 | 42 | 2 | 1 | 0.71 | 2.38 |
| 20 Jun | 276 | 32 | 0 | 1 | 0 | 3.13 |
| 21 Jun | 236 | 37 | 0 | 0 | 0 | 0 |
| 22 Jun | 169 | 31 | 1 | 1 | 0.59 | 3.23 |
| 23 Jun | 267 | 38 | 2 | 1 | 0.75 | 2.63 |
| 24 Jun | 691 | 23 | 7 | 0 | 1.01 | 0 |
| 25 Jun | 1018 | 37 | 12 | 4 | 1.18 | 10.81 |
| 26 Jun | 1092 | 32 | 5 | 0 | 0.46 | 0 |
| 27 Jun | 939 | 11 | 0 | 0 | 0 | 0 |
| 28 Jun | 948 | 19 | 7 | 0 | 0.74 | 0 |
| 29 Jun | 512 | 10 | 5 | 0 | 0.98 | 0 |
| 30 Jun | 460 | 19 | 4 | 0 | 0.87 | 0 |
| 1 Jul | 499 | 19 | 0 | 1 | 0 | 5.26 |
| 2 Jul | 597 | 8 | 0 | 0 | 0 | 0 |
| 3 Jul | 449 | 20 | 0 | 0 | 0 | 0 |
| 4 Jul | 378 | 4 | 1 | 0 | 0.26 | 0 |
| 5 Jul | 391 | 8 | 7 | 0 | 1.79 | 0 |
| 6 Jul | 374 | 2 | 6 | 0 | 1.6 | 0 |
| 7 Jul | 534 | 8 | 4 | 0 | 0.75 | 0 |
| 8 Jul | 565 | 5 | 1 | 0 | 0.18 | 0 |
| 9 Jul | 774 | 2 | 13 | 0 | 1.68 | 0 |

Appendix Table 8. Continued.

| Detection date at Bonneville Dam | Bonneville Dam detections | | Jones Beach detections | | Jones Beach detections previously detected at Bonneville (%) | |
|---|---|---|---|---|---|---|
| | Chinook salmon (n) | Steelhead (n) | Chinook salmon (n) | Steelhead (n) | Chinook salmon | Steelhead |
| 10 Jul | 1026 | 4 | 17 | 0 | 1.66 | 0 |
| 11 Jul | 905 | 5 | 0 | 0 | 0 | 0 |
| 12 Jul | 812 | 0 | 10 | -- | 1.23 | -- |
| 13 Jul | 597 | 2 | 7 | 0 | 1.17 | 0 |
| 14 Jul | 566 | 4 | 7 | 0 | 1.24 | 0 |
| 15 Jul | 849 | 1 | 1 | 0 | 0.12 | 0 |
| 16 Jul | 677 | 2 | 5 | 0 | 0.74 | 0 |
| 17 Jul | 634 | 1 | 10 | 0 | 1.58 | 0 |
| 18 Jul | 628 | 2 | 0 | 0 | 0 | 0 |
| 19 Jul | 482 | 0 | 4 | -- | 0.83 | -- |
| 20 Jul | 448 | 0 | 5 | -- | 1.12 | -- |
| 21 Jul | 499 | 1 | 7 | 0 | 1.4 | 0 |
| 22 Jul | 342 | 1 | 1 | 0 | 0.29 | 0 |
| 23 Jul | 315 | 1 | 7 | 0 | 2.22 | 0 |
| 24 Jul | 289 | 0 | 9 | -- | 3.11 | -- |
| 25 Jul | 351 | 2 | 5 | 0 | 1.42 | 0 |
| 26 Jul | 249 | 0 | 3 | -- | 1.2 | -- |
| 27 Jul | 231 | 0 | 4 | -- | 1.73 | -- |
| 28 Jul | 231 | 0 | 0 | -- | 0 | -- |
| 29 Jul | 141 | 1 | 3 | 0 | 2.13 | 0 |
| 30 Jul | 107 | 0 | 4 | -- | 3.74 | -- |
| 31 Jul | 163 | 0 | 1 | -- | 0.61 | -- |
| 1 Aug | 126 | 1 | 0 | 0 | 0 | 0 |
| 2 Aug | 47 | 0 | 0 | -- | 0 | -- |
| 3 Aug | 51 | 1 | 1 | 0 | 1.96 | 0 |
| 4 Aug | 32 | 0 | 1 | -- | 3.13 | -- |
| 5 Aug | 44 | 0 | 0 | -- | 0 | -- |
| 6 Aug | 40 | 0 | 0 | -- | 0 | -- |
| 7 Aug | 33 | 1 | 0 | 0 | 0 | 0 |
| 8 Aug | 28 | 0 | 0 | -- | 0 | -- |
| 9 Aug | 16 | 0 | 1 | -- | 6.25 | -- |
| 10 Aug | 14 | 0 | 0 | -- | 0 | -- |
| 11 Aug | 31 | 0 | 0 | -- | 0 | -- |
| 12 Aug | 37 | 0 | 1 | -- | 2.7 | -- |
| 13 Aug | 30 | 0 | 0 | -- | 0 | -- |
| 14 Aug | 14 | 0 | 0 | -- | 0 | -- |
| 15 Aug | 28 | 0 | 0 | -- | 0 | -- |
| 16 Aug | 21 | 0 | 0 | -- | 0 | -- |
| 17 Aug | 16 | 0 | 0 | -- | 0 | -- |
| 18 Aug | 25 | 0 | 0 | -- | 0 | -- |
| 19 Aug | 17 | 0 | 0 | -- | 0 | -- |
| 20 Aug | 7 | 0 | 0 | -- | 0 | -- |
| 29 Sep-30 Oct | 148 | 8 | 3 | 0 | 2.03 | 0 |
| Totals | 63,361 | 28,123 | 1,052 | 967 | 1.66 | 3.44 |